Space Log

TRW

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Introduction

The year 1989 initiated the second golden age of space science. Magellan, Galileo and the Cosmic Background Explorer (COBE) took to the skies to join veteran scientific spacecraft like Voyagers 1 and 2 — exploring our solar system, revealing the secrets of distant planets, and uncovering the origins of the universe.

- In May, the space shuttle deployed the Magellan spacecraft on a 16-month journey to Venus, where it will map the planet's surface over 22 months

- In August, the Voyager 2 spacecraft made its closest approach to Neptune, passing within 4,500 km of a planet that had been little more than a blurry blue ball as seen through powerful telescopes here on earth. After over a decade of space exploration and planetary flybys past Jupiter, Saturn and Uranus, Voyager completed its "Grand Tour"

- In October, Galileo began its circuitous trip to Jupiter, where it will drop a probe into the Jovian atmosphere in the first direct study of the solar system's largest planet

- In November, NASA launched the COBE, an unmanned observer that will measure cosmic radiation remaining from the "Big Bang" in hopes of developing a clearer picture of the early history of the universe

- In November, the 101st Congress formally approved the Comet Rendezvous Asteroid Flyby (CRAF) and Cassini missions as part of the President's FY 1990 budget. CRAF and Cassini will both fly to the outer solar system, continuing exploration in the same spirit as the intrepid Voyager 2.

NASA, with the support of the Congress and the Administration, has assured that there will be a United States-led planetary mission in its prime exploration phase — essentially continuous from 1990 to 2006. We are going back to the planets with missions to Venus, Jupiter, Mars and Saturn.

The space science missions of 1989 are prologue for the 36 science and applications missions to be launched in the next five years. We will be awash in new science data, new science discoveries.

In 1989, the United States reclaimed its position as a leader in the science of space. We have crossed over the horizon into a new era, into a second golden age. We will, in the next few years, expand our knowledge of the universe in ways which far exceed any other time in human history.

Lennard A. Fisk
Associate Administrator for
Space Science and Applications
National Aeronautics and
Space Administration

Table of Contents

Spacecraft Details 1989	1
New Spacecraft to Observe the Sun	25
The Fast Track on Orbital Traffic	35
Voyager/Neptune: Picture Perfect	43
Box Score of U.S. Launches	48
STS Payload Deployment Record	55
Payloads in Orbit	58
Worldwide Successful Space Launches	59
Satellites Decayed in 1989	60
Manned Space Flight Records	62
Summary Log of Space Launches	63

Spacecraft Details 1989

Includes most civil launches; DoD payloads not included. Spacecraft/launch data are listed chronologically. All times listed are Universal (Zulu, GMT) unless otherwise indicated. For additional details, refer to 1989 Summary Log of Space Launches.

Etalon (Kosmos 1989, Kosmos 2024)

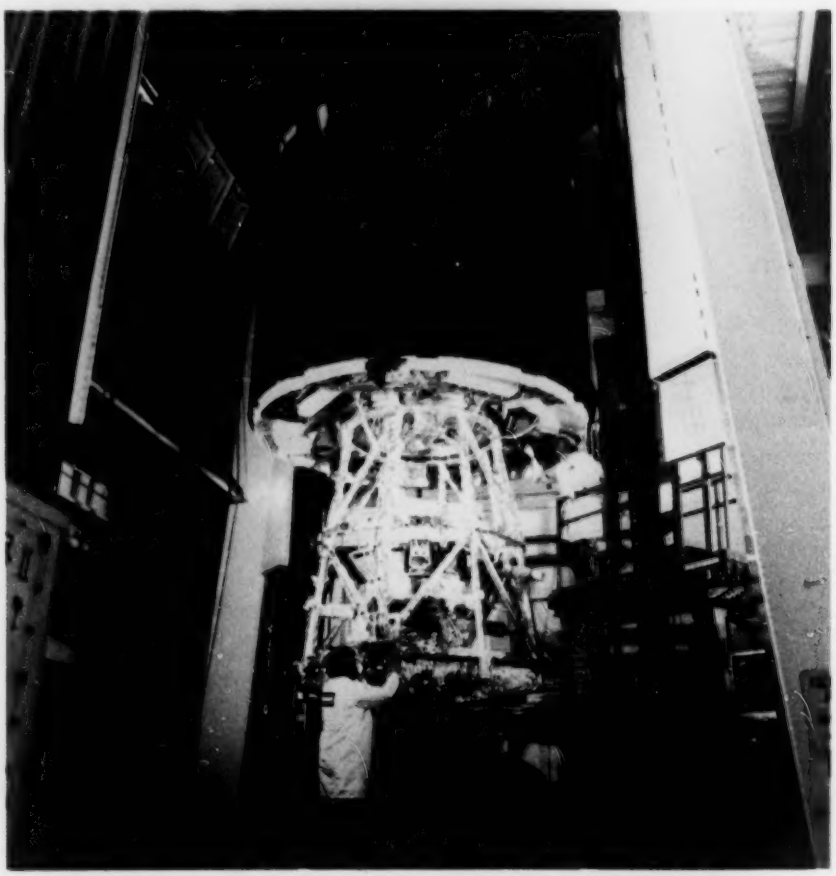
Heralding a new series of passive geodetic satellites, two Etalon Kosmos were launched from Tyuratam aboard Proton four-stage boosters (D-1-e). Each was co-launched with two payloads in the Glonass navigation system. The first Etalon (Kosmos 1989) lifted off at 02:05, January 10, the second (Kosmos 2024), 08:33, May 31. Etalon is a 1.29-m-diameter sphere, with a mass of 1,415 kg. Its surface is covered with 306 separate arrays comprising cube corner retro-reflectors with metallized faces. The satellites are used for lasar range finding, and may be similar to the U.S. Lageos launched in 1976.

INTELSAT VA-F15

The last in the INTELSAT VA series of communications satellites was launched by an Ariane 2 at 01:21, January 27. INTELSAT VA-F15, built by Ford Aerospace for INTELSAT, provides international telecommunications service from an orbital station at 60 deg. e long. The payload houses 29 C-band and six Ku-band transponders. It can accommodate 15,000 two-way voice circuits and two TV channels simultaneously; the satellite also provides maritime communications for ships at sea. The 1,977-kg INTELSAT VA-F15 is box-shaped, measuring 1.66 by 2.10 by 1.77 m; solar arrays span 15.9 m tip to tip. The arrays, supplemented by nickel hydrogen batteries during eclipse, provide 1,800 W of power at mission onset, approximately 1,280 W at the end of its seven-year design life.

GPS 2 F1, F2, F3, F4, F5

Five satellites in the 21-satellite Navstar Global Positioning System (GPS) Block 2 series were Delta-launched from Cape Canaveral AFS in 1989. When complete, the constellation will provide precise position data—accurate to within 16 m—to military and civilian users worldwide. Navstar signals can be received on devices as small as a telephone. The first GPS Block 2 flew at 18:29, February 14, aboard the first Delta 2 launch vehicle. The new generation Delta is 4.2 m taller and 13 percent more powerful than its predecessor. It can boost 3,982 kg into low-earth orbit, 1,447 kg into geotransfer orbit. GPS 2 F2 lifted off at 22:19, June 10. Flight 3 was launched at 05:58, August 18; Flight 4, 09:31, October 21; and Flight 5, 18:10, December 11. The GPS 2 satellites, built by Rockwell International for Air Force Space Systems Division, weigh 1,665 kg at launch, 840 kg on orbit. Each has a 7.5-year design life. The Air Force intends to launch a GPS every two to three months until the constellation of 21 operational satellites and three spares is aloft. The Block 2 Navstars join seven operational Block 1 satellites.



JCSat

JCSat 1, 2

The first Japanese Commercial Communications satellite was launched into geotransfer orbit, 23:29, March 6, by an Ariane 44 LP. Privately owned and operated by JCSAT, a joint venture between Hughes Space & Communications Group, C. Itoh & Co. Ltd. and Mitsui & Co, Ltd., JCSat provides Japanese businesses with telephone, TV, facsimile and data services. High quality video and message data can be received on user antennas as small at 1.2 m. The first of the new Hughes HS 393 series, JCSat measures 3.7 m by 10 m fully extended and with its 2.3-m antenna deployed. It weighed 2,280 kg at launch; 1,364 kg on orbit. Body mounted solar cells provide 2,200 W; two nickel hydrogen batteries power JCSat in shadow. The Ku-band communications payload provides 32 channels, each able to handle one TV broadcast or 250 telephone circuits. JCSat separated from the Ariane third stage 20 minutes after launch. The first of four apogee motor firings commenced 26.5 hrs later, boosting the commsat towards its orbital slot at 150 deg. e. JCSat 2 flew aboard the first commercial Titan III at 00:07, January 1, 1990. Liftoff time at the Eastern Test Range was New Year's Eve, making the Titan III dual launch (see Skynet 4A, p21) the last unofficial flight of 1989 as well as the first designated launch of 1990. The second JCSat in the two-satellite series is assigned to 154 deg. e.

MOP-1

The first Meteosat Operational Program satellite was dual launched with JCSat aboard an Ariane 44LP, 23:29, March 6. MOP-1 carries an imaging radiometer with four independent channels: two capture images in the visible spectrum, two in the infrared (water vapor and thermal). The satellite images earth's cloud cover every 30 minutes. Data is transmitted in near real time to a central processing station in Darmstadt, West Germany. Processed data is retransmitted through MOP-1 to some 1,000 users throughout Europe and Africa. MOP-1, renamed Meteosat 4 after checkout, follows three pre-operational Meteosat missions that have, since F1 in 1977, participated in the World Weather Watch and validated the European meteorological satellite program. ESA manages the program's satellite segment for Eumetsat, a 16-nation organization. Built by Aerospatiale, the operational Meteosat is 2.1 m in diameter, 3.1 m tall. Body mounted solar arrays provide 387 W of power. It weighed 681 kg at launch, 316 kg on orbit. Meteosat 4's solid apogee motor fired 37 hours after launch, boosting it to geostationary orbit at 0 deg. The satellite returned its first earth image in April and was declared operational June 19. It has a five-year life expectancy.

STS-29

The shuttle Discovery lifted off from Kennedy Space Center pad 39B at 14:57, March 13, carrying a five-man crew, a communications satellite and six onboard experiments. The 28th shuttle mission, the eighth for Discovery, was commanded by Michael L. Coats and piloted by John E. Blaha. Also aboard were mission specialists James F. Buchli, Robert C. Springer and James P. Bagian. Total liftoff weight was 2,049,888 kg, 119,269 kg of which was the orbiter and cargo. The Tracking and Data Relay Satellite (TDRS) was deployed 6 hrs, 13 mns after liftoff. With two TDRS's fully operational (F1 launched in April 1983; F3 in September 1988), STS-29/ground communications were uninterrupted over 85 percent of each orbit — a fourfold improvement over pre-TDRS system shuttle flights. Following TDRS deployment — the mission's primary aim, the crew monitored experiments, assisted in calibration tests with the Air Force Maui Optical Site and filmed earth with an IMAX camera. One experiment, the Space Station Heat Pipe Advanced Radiator Element, a test of a new cooling system, failed when the cooling medium failed to move through the 15.7-m pipe. Discovery executed five somersaults on mission day five in an attempt to get the fluid moving. To no avail; the experiment is being redesigned for future flight tests. Discovery landed on Edwards AFB runway 22 at 14:36, March 18, after 4 days, 23 hrs, 39 mns in orbit.

TDRS 4

The fourth in a series of Tracking and Data Relay Satellites was deployed from STS-29 at 21:10, March 13. One hour later, the IUS firing sequence began, boosting the commsat towards a 36,000-km orbit. TDRS 4, able to relay two-way S, Ku and C-band signals from low-earth orbiting satellites to a single dedicated ground station, completes the TDRS system (TDRSS). Two satellites and an on-orbit spare assure communications coverage for 85 percent of a given satellite's orbit. Ground stations can provide only 15-20 percent coverage. Since TDRSS became fully operational, July 26, NASA announced plans to close five stations. TDRS 4,

TDRS Deployment

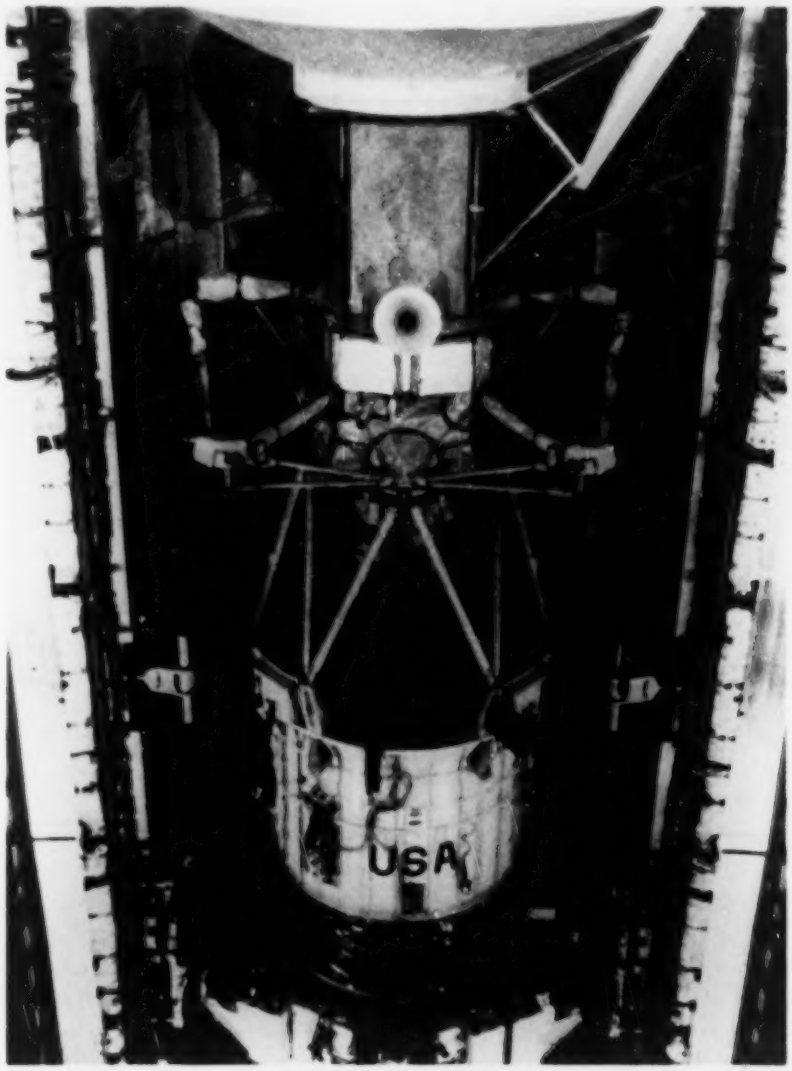
stationed above 41 deg. w long., replaces the 6-year-old TDRS 1. That satellite is now the system spare at 79 deg. w. F3 is stationed above 171 deg w. F2 was lost with the Challenger. TDRS 4 was built by TRW Space & Technology Group for Contel, which leases the system to NASA. Weighing 2,120 kg on orbit, it measures 17.41 x 12.98 m with solar arrays deployed. Solar cells provide 1,850 W of power at the end of its 10-year design life; three nickel cadmium batteries supply power during eclipse. The communications payload includes 21 channels offering data rates from 100 bps to 300 Mbps. TDRS 4 can service up to 22 user satellites simultaneously on one S-band multiple access channel. Twelve C-band transponders are set aside for commercial use.

Tele-X

A joint venture of Sweden, Norway and Finland, Tele-X is the first Nordic telecommunications satellite. Launched aboard the last Ariane 2, 02:28, April 2, Tele-X provides direct TV broadcast to home receivers and video conferencing and data transmission service to business users in Northern Europe. Three high power channels operating in 17/12 GHz accommodate direct broadcast. EIRP is 61 dBW; traveling wave tube (TWT) power output of 230 W enables signals to be received on antennas as small as 30 cm. Two channels, operating in 14/12 GHz, can serve the video and data needs of up to 5,000 business users. Tele-X was built for the Swedish Space Corporation by Aerospatiale/Eurosatellite. The satellite measures 2.4 by 1.65 by 5.0 m with antennas deployed. Solar arrays span 19 m tip to tip and provide 3.6 kW of power. It weighed 2,142 kg at launch, 1,277 kg with transfer fuel depleted. Three apogee motor firings boosted Tele-X into geosynchronous orbit where it arrived on station at 5 deg. e on April 14. It has a six to eight-year life expectancy.

Foton 2

Introduced by name in 1988, the Foton satellites house a Vostok-derived materials processing laboratory. Foton 2, carrying French commercial microgravity experiments, was launched from Plesetsk by a Soyuz (A-2) booster at 17:00, April 26. It was recovered May 11. The satellite comprises a stubby cylinder—probably holding chemical batteries—at the front, a spherical 2.3-m-diameter reentry vehicle and a double-cone instrument/retro module. Its mass is six metric tons. Foton 2 is the fifth flight of the series. The same reentry module flew as Kosmos 1841 in 1987 and Foton 1 in 1988. Previous versions flew as Kosmos 1645 in 1985, and Kosmos 1744 in 1986.



Magellan

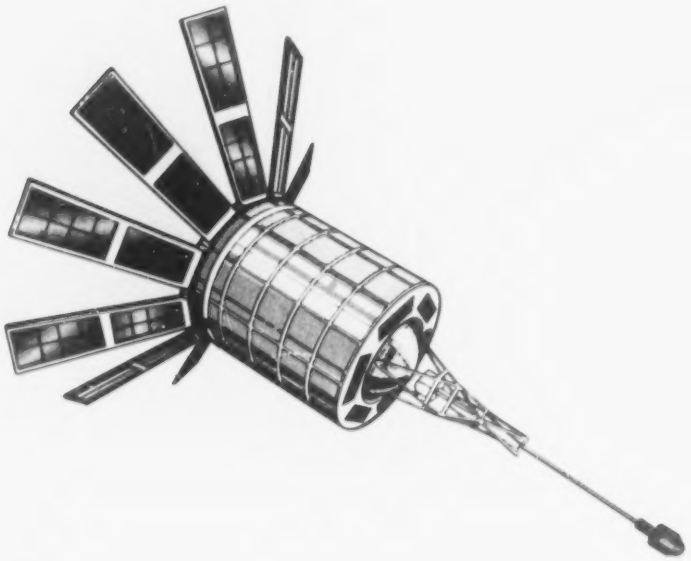
STS-30

With the first interplanetary spacecraft launched by the U.S. in 11 years stowed in its cargo bay, the shuttle Atlantis lifted off from Kennedy Space Center, May 4 at 18:47. The Magellan Venus mapper was deployed 6 hrs, 14 mns later on orbit five. Because the Magellan/IUS took up most of the shuttle's cargo weight allowance, few other payloads could be accommodated on STS 30. The Mesoscale Lightning Experiment was aboard to observe nighttime lightning activity; the Fluids Experiment Apparatus was flown for crystal growth research. Combined orbiter/cargo weight at liftoff was 98,533 kg; total launch weight was 2,049,877 kg. Crew members for Atlantis' fourth flight included Commander David M. Walker; Pilot Ronald J. Grabe; and Mission Specialists Mark C. Lee, Norman E. Thagard and Mary L. Cleave. The crew proved its ability to replace a computer on orbit when one of five general purpose computers failed on mission day four. Although the failure was non-threatening, flight controllers welcomed the opportunity to replace the unit. Each shuttle flight carries a spare computer and each crew is trained for changeout; this was the first time such a replacement was called for. The task was successfully completed in 4.5 hrs. STS-30 ended on Edwards AFB runway 22 at 19:43, May 8 after 64.5 orbits. Mission duration was 4 days 56 mns.

Magellan

The first planetary probe launched via shuttle was deployed from the Atlantis cargo bay at 01:01, May 5. One hour after Magellan was ejected, the two-stage IUS fired, casting the 3,445-kg spacecraft onto a 15-month-long trans-Venus trajectory. The 41-million-km cruise will take Magellan around the sun one and a half times to rendezvous with Venus in August 1990. At Venus, a Star 48 motor will fire to insert Magellan into a 250 km by 8,029 km near-polar elliptical orbit. From there, a Synthetic Aperture Radar (SAR) will map some 90 percent of the planet's surface at a resolution of 120 to 300 m. Radar was selected over visible light imaging because it can "see" through Venus' thick cloud cover. The SAR will produce 1,852 image swaths, each covering terrain from 17 to 28 km wide and 15,996 km long. The swaths will be compressed into mosaic maps of the planet. Surface feature height will be measured with 30-m accuracy by Magellan's altimeter. This data, combined with radio measurements, will give scientists the most accurate picture to date of Venus' structure and geology, geophysics and small-scale surface physics. The mission is planned to last 243 days, Venus's rotational period. Built by Martin Marietta from off-the-shelf hardware, Magellan is 6.46 m tall and 4.61 m in diameter. Solar panels, supplemented in shadow by two nickel cadmium

batteries, provide 1,545 W. The SAR was built by Hughes Space & Communications Group; the program is managed by JPL. The first of three trajectory correction maneuvers was executed May 21; a second, March 13, 1990. The final correction is scheduled for 17 days before orbital insertion.



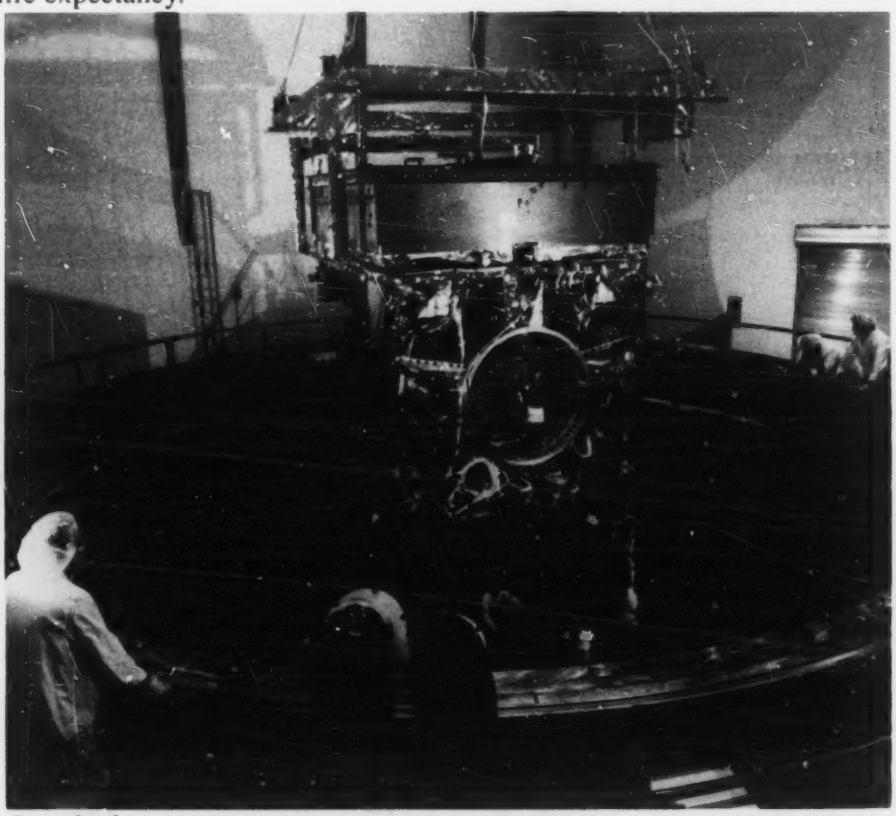
GEO-IK, courtesy Teledyne Brown Engineering

GEO-IK (Kosmos 2037)

The Soviets report that Kosmos 1950, launched May 30, 1988, was a geodetic satellite known as GEO-IK. Kosmos 2037, launched from Plesetsk, 00:19, August 28, by a Tsyklon (F-2) is a similar payload. The satellite design is based on the small Kosmos navigation series, measuring 2 m in diameter and 2.1 m long with a boom extending from the top. Mass is about 900 kg. GEO-1K is oriented with its long axis pointing toward earth. Transmission frequencies are given as 150 MHz and 400 MHz. It can be tracked by laser or by onboard flashing lights. Earlier unacknowledged flights in the series may include Kosmos 1312, 1410, 1589 and 1803 at 82.6 deg. inclination; and Kosmos 1510, 1660, 1732 and 1823 at 73.6 deg.

Superbird 1

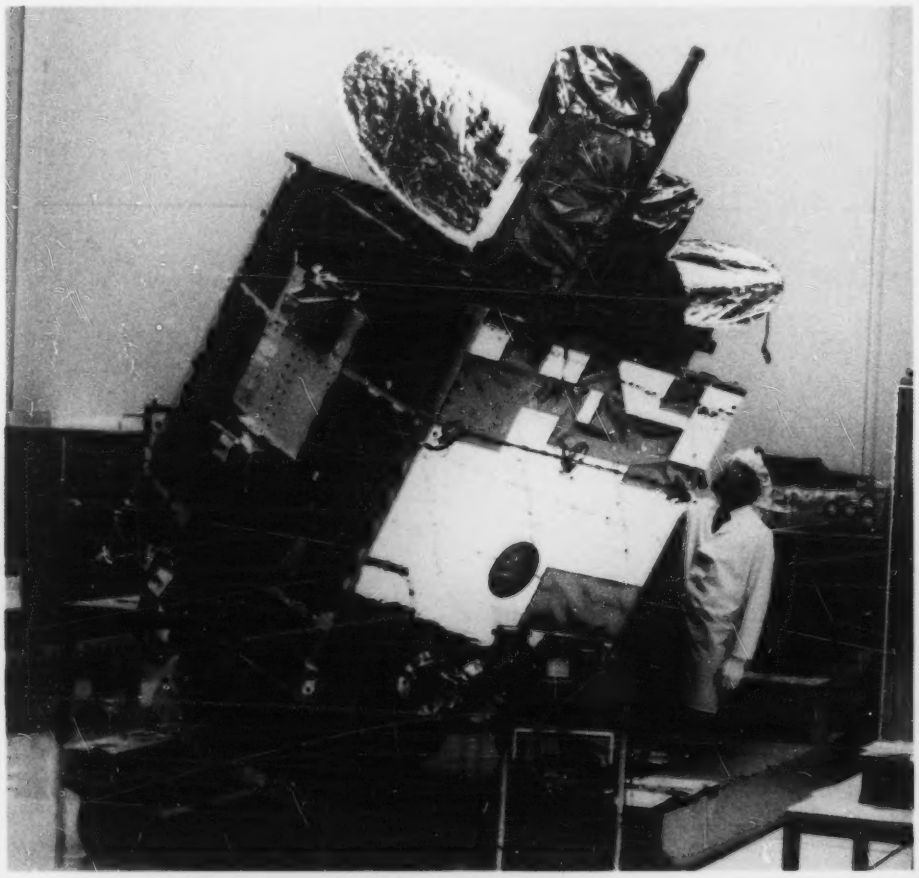
The Japanese telecommunications satellite, Superbird 1, was launched aboard the most powerful version of the Ariane 4 series, the 44L, June 5 at 22:37. Owned by the Space Communications Corporation (SCC), Superbird 1 provides video distribution, news gathering, remote publishing and high definition TV service to the main islands of Japan and Okinawa. The satellite is geared primarily to the business community. It carries 19 Ku-band and 10 Ka-band transponders, with three of the Ka-band channels beamed to the Tokyo area exclusively. Superbird 1, built by Ford Aerospace, is the first of two SCC commsats. Based on Ford's INTELSAT V series, it is box-shaped with antennas mounted on three sides. It measures 2.41 by 2.58 x 2.20 m. Deployed solar arays span 20.3 m and provide a maximum 3,984 W of power. Two nickel hydrogen batteries supplement power during eclipse. Superbird 1 weighed 2,489 kg at launch, more than half the lift capability of the Ariane 44L. The three-stage, 58-m long Ariane, equipped with four liquid strap-on boosters can loft 4,200 kg into transfer orbit. Placed into an intial 185 x 35,981-km orbit by Ariane, Superbird 1 was subsequently boosted to geosynch by three apogee motor firings. Stationed above 158 deg. e, it has a 10-year life expectancy.



Superbird

DFS Kopernikus 1

Dual-launched with Superbird aboard an Ariane 44L, the West German telecommunications satellite DFS Kopernikus 1 flew into orbit June 5 at 22:37. The Deutsche Bundespost (DBP) satellite is one segment of an expanded telecommunications system, supplementing The Federal Republic of Germany's existing national terrestrial network. DFS Kopernikus 1 will provide DBP cable TV networks with satellite programs, accommodate 1,800 telephone and 200 data lines between FRG and West Berlin, and offer a closed data transmission network to subscribers. The payload houses 11 transponders: three operating at 14/11 GHz and seven at 14/12 GHz. One 30/20 GHz channel is on board for future use. The first of two satellites in the system, DFS Kopernikus 1 was built for DPB by Consortium R.DFS, led by MBB/ERNO. It measures 4.15 m by 15.40 m with solar arrays deployed, and weighed 1,416 kg at launch, 645 kg on orbit. It is powered by 1,500 W over its 10-year service life. The satellite drifted to its assigned station at 23.5 deg. e after three apogee motor firings boosted it to geosynchronous orbit.



DFS Kopernikus 1, courtesy of Bruce Battrick

Resurs-F1, Resurs-F2

The Resurs-F series of remote sensing satellites flew prior to 1989, however earlier flights were given Kosmos designators. Based upon the Vostok manned spacecraft, Resurs-F has a spherical reentry module that can be flown up to three times, an instrument/retro module and a forward orbital maneuvering engine. Total mass is 6.3 metric tons. The satellites are launched from Plesetsk aboard Soyuz class (A-2) boosters. Resurs-F1 missions typically last two weeks, although they can stretch to 25 days. Resurs-F2 flies longer missions with a claimed maximum of 45 days. Resurs-F1 carries camera systems for sky, spectrozonal and topographic photography; Resurs-F2 carries cameras for sky and multi-spectral images. Film is returned to earth via the reentry modules. Both series can accommodate piggyback payloads. Resurs-F1 Flight 1 was launched at 08:05, June 27 and reentered July 11. Resurs-F1 2 lifted off at 10:49, September 6 and returned September 22. It carried a commercial microgravity experiment for the Federal Republic of Germany. Resurs-F2 1, launched 08:50, May 25, deployed two Pion passive atmospheric research satellites June 9 before reentering June 17. The second Resurs-F2 mission began 09:05, July 18. A second pair of Pion satellites were deployed August 7; reentry was August 8. Resurs-F2 3 commenced 10:29 August 15 and ended September 14.

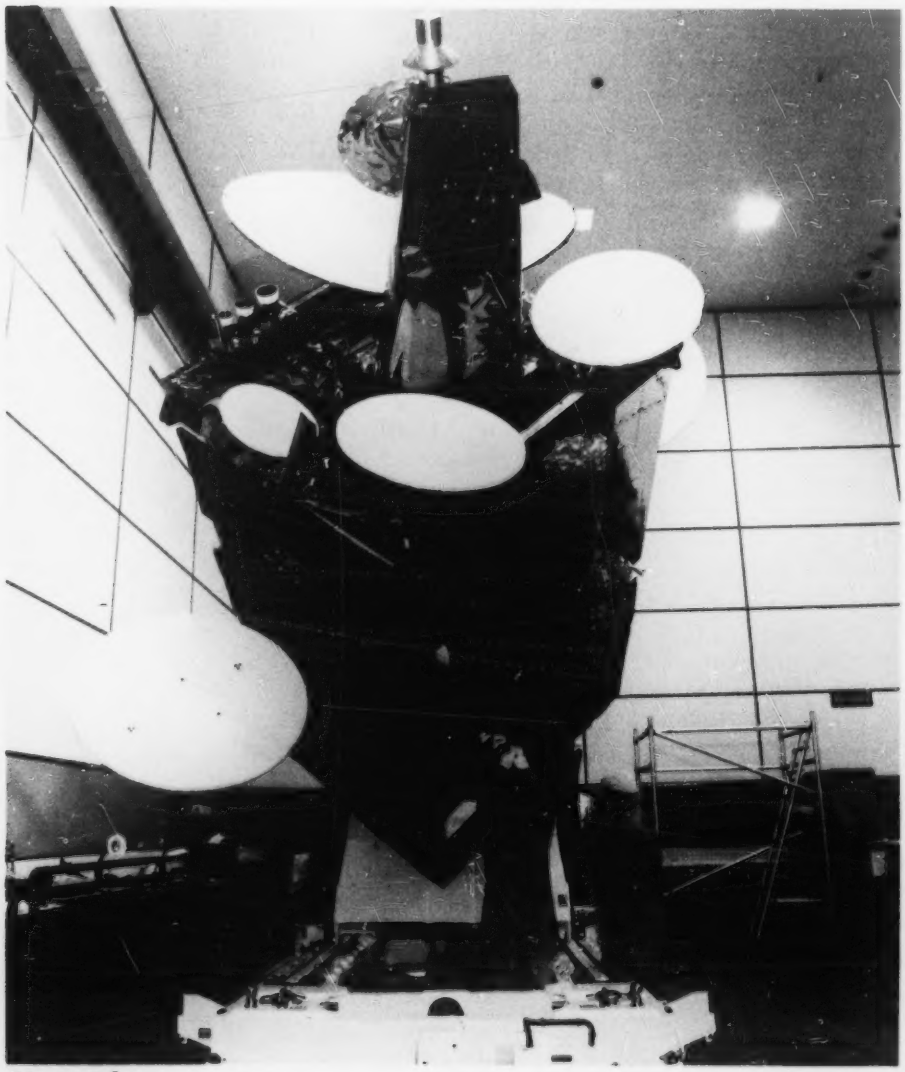
Nadezhda 1

Flown for the first time with a designator other than "Kosmos," the Nadezhda civil navigation satellite lifted off from Plesetsk, 15:22, July 4 by a Kosmos (C-1) booster. Carrying transponders for the COSPAS/SARSAT international search and rescue system, the satellite is also designated Cospas 4. It is a cylinder, 2 m in diameter, 2.1 m long, with an extended boom. Mass is about 825 kg. Nadezhda 1 is co-planar with Cosmos 1791 and, presumably, replaces it. Other satellites in the system include Kosmos 1655, launched in 1985; Kosmos 1816 and Kosmos 1861, launched in 1987.

Olympus 1

The last Ariane 3 lofted the European communications technology demonstration satellite, Olympus 1, into transfer orbit at 00:14, July 12. Olympus 1 carries four communications payloads introducing new satellite services and techniques to European users. A powerful direct broadcast system (EIRP is 62.5 dBW) offers one channel for Italian TV and one for international programming throughout Europe; both transmit at 12 GHz, signals

can be received on 45-cm ground antennas. A 12/14 GHz specialized services payload accommodates switching and frequency reuse experiments, videoconferencing and data distribution. A 20/30 GHz Ka-band payload offers point-to-point and multipoint videoconferencing, tele-education and low-speed data handling. A 12/20/30 GHz package performs propagation research. Built by British Aerospace for ESA, Olympus 1 measures 2.9 by 2.7 by 5.5 m. Solar arrays, spanning 25.6 m, provide 3.6 kW of power. Olympus 1 weighed 2,595 kg at launch; 1,450 kg on orbit. It has a five-year design life. The Olympus bus is designed to handle double the power, mass and service life requirements on future missions. A single burn of Olympus 1's bipropellant Liquid Apogee Engine gave the satellite a soft ride towards its assigned station at 19 deg. w, where it arrived August 3.



Olympus 1

STS-28

The oldest shuttle orbiter Columbia, having undergone extensive return-to-flight refurbishment, was launched on a DoD mission at 12:37, August 8. Columbia was the last of the orbiters to be retrofitted with some 250 modifications — changes ranging from a crew escape system, improved wiring and thermal protection, to replacements for individual brackets, blankets and panels. Because of its age and flight history, the veteran spacecraft required more attention than its sister orbiters. Its first flight since January 1986 marked the successful completion of the fleet upgrade in the post-Challenger era. Ten seconds after launch, Columbia underwent a 140 deg. roll maneuver, targeting it for a 57 deg. inclination. The STS-28 crew included Commander Brewster H. Shaw, Pilot Richard N. Richards and mission specialists David C. Leestma, James C. Adamson and Mark N. Brown. Columbia touched down on Edwards AFB runway 17 at 13:37, August 13 after 5 days, 1 hr in space.

TV-Sat 2

Dual-launched aboard an Ariane 44 LP at 23:25, August 8, TV-Sat 2 was succesfully boosted towards geosynchronous orbit 36 hrs, 40 ms later with the first of three apogee motor burns. From its position at 19 deg. w, the West German direct broadcast satellite beams five high power TV channels to 60-cm receiving antennas in Germany and 90-cm antennas in Western Europe. TV-Sat 2 was built by Eurosatellite GmbH for the Deutsche Bundespost. It replaces TV-Sat 1, which was abandoned as a commercial vehicle when its receiving antenna could not be deployed. The satellite is the West German segment of a joint French/West German effort to coordinate broadcast service from a shared geosynchronous station. TV-Sat 2 has an EIRP of 64.5 dBW; transmitting at 11/12 GHz, receiving at 17/18 GHz. The satellite weighed 2,130 kg at launch, 1,027 kg on orbit. It measures 6.3 by 18.9 m with antennas and arrays deployed. Solar arrays provide 3.2 kW of power over its nine-year design life.

Hipparcos

Hipparcos, an ESA astrometry satellite designed to measure the precise positions, parallaxes and motions of stars, was launched aboard an Ariane 44LP, 23:25, August 8. The 1,130-kg satellite, built for ESA by a European consortium headed by Matra, houses a 290-mm all reflective Schmidt telescope. A beam combiner brings light from two 0.9 x 0.9 degree fields of view—58 deg. apart— onto a single focal surface. This feature enables large and small field measurements to be taken at the same

Hipparcos, courtesy of ESA

time and allows the true angle between stars in both fields to be determined based on the 58-deg. known angle. Redundant star mappers supply real-time satellite attitude data as well as astrometric and two-color photometric measurements. The name Hipparcos, for High Precision Parallax-Collecting Satellite, honors Hipparchus, who calculated the moon's distance from earth in 120 BC by measuring its parallex. Hipparcos was expected to provide measurements, accurate to 0.002 arc seconds, on 120,000 stars, and less exact measurements on another 400,000. Bound for its geosynchronous station at 12 deg. w, Hipparcos was left in a highly elliptical orbit when its apogee kick motor failed 37 hours after launch. Repeated firing attempts also failed, forcing controllers to use the satellite's thrusters to boost it some 300 km. From the resulting modified transfer orbit, mapping accuracy will be reduced by a factor of 10, repetitious star sightings will shrink from 80 to 10. Data loss can be limited to about 10 percent, however, by adding ground stations to the Hipparcos network. There is enough stored power to handle its 295-W requirements during longer eclipse periods, but Hipparcos' 2.5-year service life may be degraded by repeated passes through the Van Allen belts.

Marcopolo 1 (BSB 1)

The first of two privately owned British direct-to-home broadcast satellites was launched from Cape Canaveral aboard a Delta 1, 22:59, August 27. It was the first commercial launch for a U.S. launch vehicle and also heralded a new industry trend wherein the satellite maker must certify that the vehicle is safely in orbit before transferring control to the operator. Hughes Space & Communications Group designed and built Marcopolo 1 for British Satellite Broadcasting Ltd. (BSB), and purchased insurance and launch vehicle service as well. Based on the standard Hughes H376 bus, Marcopolo 1 is 2.1 m in diameter and 2.7 m tall when stowed. With solar drum deployed and antenna reflector raised, it extends to 7.2 m. It weighs 1,220 kg at launch, 660 kg on orbit. The payload houses five 110-W Ku-band channels for direct broadcast to users with antennas as small as 0.3 m. The satellite's high power requirements are fulfilled via longer solar panels covered with large area solar cells, and nickel cadmium batteries. Output at the beginning of its 10-year life is 1,100 W. Marcopolo's apogee kick motor was fired 38 hrs, 53 mns after lift off, boosting the BSB commsat towards its geosynchronous station at 31 deg. w. It arrived there August 31. Commercial service is expected to commence in 1990.

GMS-4

Japan's fourth weather satellite was launched via an H-1 vehicle from Tanegashima Space Center, 19:11, September 5. The Geostationary Meteorological Satellite replaces the five-year-old GMS-3, monitoring weather conditions over 104 million square km of the Pacific basin. GMS-4, also called Himawari-4, carries a visible and infrared spin scan radiometer that senses radiation, and images the earth and surrounding atmosphere. Scanning about 1/100 degree with each satellite revolution, the device produces a complete image in 25 minutes. An onboard space environment monitor studies the effects of solar activity on telecommunications system. GMS-4 differs slightly from GMS-3. In an effort to improve reliability, the conventional tungsten lamp flown on GMS-3 was replaced with one containing light emitting diodes. A transparent thin film was applied to the satellite surface to curb electrostatic discharge. GMS-4 was built by Hughes Space & Communications Group for NASDA. It is 2.1 m in diameter, 3.45 m high and weighs 725 kg at launch, 329 kg on station. Stationed above 140 deg. e, it has a five-year design life.

FltSatCom F8

The last in a series of Fleet Satellite Communications satellites was launched from Cape Canaveral AFS at 8:56, September 25, aboard an Atlas Centaur. It was the last Atlas launch that NASA will manage; future unmanned NASA launches will be contracted from the private sector. FltSatCom provides worldwide UHF voice and teletype communications for U.S. armed forces. It is specifically designed to communicate with small, inexpensive terminals used by field troops, and platforms aboard aircraft, ships and submarines. Twelve UHF channels are used by the Air Force, 10 by the Navy and one by the National Commmand Authority. An experimental EHF package aboard Flight 8 is a test bed for next-generation communications systems. Built by TRW Space & Technology Group, the 2,310-kg satellite's hexagonal body measures 2.46 m in diameter and 6.76 m high. It hosts an 18-turn helical UHF receive antenna and 4.9-m transmit antenna. Two 2.76 by 4-m solar panels and three nickel cadmium batteries provide 1,500 W of power over its 5-year service life. FltSatCom F8 joins five operational satellites that have served the DoD since 1978. FltSat F5 was disabled during a launch mishap; F6 was lost at launch.

FltSatCom F8

Interkosmos 24, Magion 2

A science mission investigating the propagation of electromagnetic waves in the ionosphere, Interkosmos 24/Magion 2 were launched via a Tsyklon (F-2) booster at 00:01, September 28 from Plesetsk. Also known as Aktivny-1K, or Active, Interkosmos 24 transmits 10.5-kHz radio waves to the co-orbiting Magion 2, which was deployed from the primary satellite, October 3. The 50-kg Magion 2 was built by Czechoslovakia. The Soviets invited investigators from the TRW Space & Technology Group to receive the low-frequency radio waves and participate in the propagation experiment. In turn, TRW invited high schools nationwide to join the study. Inexpensive ground station "kits" were supplied to 100 schools, allowing students to build their own receiving stations. Unfortunately, technical problems aboard both satellites have prevented the signals from being received. The student stations can, however, be used in other similar studies.

STS-34

The shuttle Atlantis, carrying its second interplanetary payload of the year, was launched at 16:53, October 18, from pad 39B at Kennedy Space Center. Nine seconds after liftoff, Atlantis executed a 120-deg. roll maneuver, aligning its trajectory for an orbital inclination of 34.4 deg. Combined orbiter/cargo weight at launch was 119,943 kg; total liftoff weight was 2,049,285 kg. Atlantis had undergone 34 modifications since its STS-30 mission, among them, a cooling system added to dissipate heat from the radioisotope thermoelectric generator on its primary cargo—the Galileo Jupiter spacecraft. STS-34 was commanded by Donald E. Williams and piloted by Michael J. McCulley. Shannon W. Lucid, Franklin Chang-Diaz and Ellen S. Baker were mission specialists. The crew deployed Galileo 6 hrs, 21 mns into the flight. Six onboard experiments, including one student involvement project, were attended to over the next three days of the mission. Crew members also photographed environmentally sensitive areas of earth for an IMAX film. Forecasted high winds forced Atlantis to land two orbits ahead of schedule, at 16:32, October 23. STS-34 ended on Edwards AFB runway 23 after 4 days, 23 hrs, 39 mns.

Galileo

The first leg of a circuitous 3.8 billion-km journey to Jupiter commenced October 18 at 23:14, when the Galileo spacecraft was deployed from the shuttle cargo bay. Galileo will enter Jupiter orbit in December 1995. For 22 months, 10 instrument/experiments will study the planet's atmosphere,

satellites and magnetosphere; a high-resolution camera will return some 50,000 color images from vantage points unattainable by the Voyager flybys. One hour after shuttle deployment, the two-stage IUS cast Galileo onto a complex Venus-Earth-Earth gravity assisted trajectory to Jupiter. The original mission called for a Centaur upper stage to send Galileo on a more direct 2.5-year sojourn to Jupiter. Following the Challenger disaster, the liquid-fueled Centaur was deemed too volatile for a manned shuttle flight. The alternative solid-fueled IUS is not powerful enough to propel Galileo onto a direct trans-Jupiter trajectory. A gravity assist at Venus in February 1990 sped Galileo back towards earth. Two earth passes, in December 1990 and December 1992, will give it added velocity to reach Jupiter six years after launch. Enroute, Galileo will collect data and images at Venus, the Earth, the moon and, in October 1991, the asteroid Gaspra. Five months before entering jovian orbit, Galileo will dispatch a probe into the core of the gas giant. The probe's six instruments are expected to identify atmospheric material and conditions that cannot be remotely detected. The probe descent phase will last about 75 minutes before it is crushed by Jupiter's atmosphere. The Galileo orbiter is 4.6 m tall; its high-gain antenna is 4.8 m in diameter, the magnetometer boom extends 10.9 m. It weighed 2,374 kg at launch, laden with 1,087 kg of fuel. The fuel will power some 30 scheduled correction maneuvers. Transmitters operate at S and X-band, at a maximum 134 kilobits per second. Far from the sun, Galileo depends on radioisotope thermoelectric generators for power—570 W at the onset, 480 W at end of life. The spacecraft was designed and built by JPL, which also manages the program. Hughes Space & Communications Group built the probe, which weighs 337 kg and measures 125 by 86 cm. Galileo can operate beyond its scheduled 22-month mission, as long as thruster fuel remains.

INTELSAT VI-F2

Packing a communications payload able to transmit up to 120,000 telephone calls and three TV broadcasts simultaneously, a new generation INTELSAT VI communications satellite lifted off aboard an Ariane 44L, at 23:05, October 27. Intelsat VI carries 38 C-band and 10 K-band transponders. Advanced digital circuit multiplication equipment can increase its average 24,000 simultaneous telephone circuit capacity to 120,000 during peak hours. Satellite Switched Time Division Multiple Access (SS/TDMA), flying commercially for the first time, permits users to interconnect beams between satellites for faster routing. Built by Hughes Space & Communications Group for INTELSAT, INTELSAT VI measures 3.6 m in diameter and 5.3 m tall when stowed. It stretches to 11.7 m with solar drum extended. The satellite is the heaviest commercial commsat flying to date, weighing 4,215 kg at launch, 2,560 kg on orbit. Two nickel hydrogen batteries supplement the solar arrays to provide

Galileo

2,252 W minimum. It has a 13-year design life. The first firing of INTELSAT VI's liquid apogee motor ocurred 5 hrs, 32 mns after launch. The satellite reached geosynchronous orbit four days later after five additional burns. INTELSAT VI is slated to begin operation in March 1990 at 24.5 deg. e.

Cosmic Background Explorer (COBE)

The first of a new breed of astrophysical satellites was launched at 14:34, November 18, aboard the last NASA-owned expendable launch vehicle. The Delta 5920 lifted off from Vandenberg AFB, boosting the Cosmic Background Explorer into a 900-km polar orbit. From there, three onboard instruments will measure diffuse infrared radiation that abounds in the universe. Scientists believe this energy, which pummels earth from all directions, originated with the big bang. Data returned over the one-year mission will tell scientists about the structure of the early universe, how energy was released, and how galaxies were formed. COBE, designed, built and managed by NASA Goddard Space Flight Center, was originally planned for a shuttle launch. After the 1986 Challenger accident, the satellite was scaled down to meet Delta launch criteria. Overall weight was reduced from 4,530 kg to 2,265 kg. Its 4.6-m-diameter body shrank to 2.45 m. On orbit, a deployed protective shield increases COBE's width to 4 m, the communications antenna lengthens it to 5.8 m. Three 8.6-m solar arrays provide 1,000 W of power. COBE's mission kicks off a scientific focus on astrophysics that will continue with the forthcoming launches of NASA's Great Observatories, Rorsat and several new Explorer satellites.

STS-33

The shuttle Discovery lifted off from Kennedy Space Center on a DoD mission, 00:23, November 23. STS-33 carried a military payload and a five person crew: Commander Frederick D. Gregory; Pilot John E. Blaha; Mission Specialists Manley L. Carter, Story F. Musgrave and Kathryn C. Thornton. Discovery's scheduled reentry was postponed from the night of November 26 to the following afternoon due to high winds at the Edwards AFB landing site. Continued strong crosswinds and tailwinds forced an additional one orbit delay and a last minute runway change following the deorbit burn. STS-33 touched down on runway 04, at 09:31 November 28, completing a 5 day, 8 mn mission.

Granat

Originally called Astron 2, Granat is an X- and gamma ray astronomical observatory studying high energy emissions from galactic and extra-galactic sources. It was launched from Tyuratam, December 1 at 20:20 by a four-stage Proton (D-1-e) booster. The observatory is based on the main bus design of earlier Venera and VEGA missions. It is cylindrical, about 4 m long and 2.5 m in diameter. Two solar panels extend from either side of the main body. Mass is about 4 metric tons, with 2.3 metric tons of experi-

ments. The major experiment is a French Sigma coded-mask gamma radiation telescope. It measures 3.5 m by 1.2 m diameter and has a 4.45 by 4.20 deg. field of view. The satellite also carries a spectroscope and an X-ray imaging telescope. The astrophysics payload was developed in cooperation with France, Bulgaria and Denmark. The Granat mission was expected to last 18 months; however lengthy ground delays may have reduced its on-orbit life to eight months.

Skynet 4A

The New Year's Eve launch of Skynet 4A and JCSAT 2 (see p. 3) aboard the first commercial Titan III clocked in at 00:07, January 1, 1990, UT. The dual launch is the first official space flight (1990 001) of the new year; but its 07:07 EST liftoff gives it "last of 89" honors in the western hemisphere. The launch from Cape Canaveral inserted Skynet into a low-earth parking orbit. The commercial Titan III is a two-stage liquid-fueled vehicle with two solid propellent motors affixed to its core. Its 246,288,000 lb/sec thrust can deliver 14,496 kg into low-earth orbit. A PAM-2, serving as a third stage, boosted Skynet towards its assigned geostationary position at 6 deg. e. Skynet 4A is the second in a series of three UK Ministry of Defense satellites. It provides jam-proof communications service between fixed and mobile land and sea-based ground stations. The communications payload houses one four-channel SHF transponder and one two-channel UHF transponder. The British Aerospace-built commsat measures 2.1 m by 1.4 m and weighs 1,463 kg at launch. Sixteen-meter solar arrays provide 1,200 W over its seven-year design life.

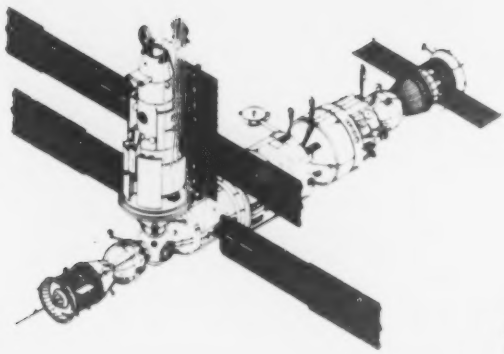


Illustration by Daniel Gauthier

Mir Details

Cosmonauts Alexander Volkov, Sergei Krikalev and Valeriy Polyakov spent the first four months of 1989 performing routine medical experiments and making earth and astronomical observations aboard the Soviet space station. The Progress 40 resupply ship arrived February 12. After undocking on March 3, it deployed two large folded structures mounted on its exterior. The Mir crew photographed the deployment as the material unfolded and took shape automatically. The structures are believed to be applicable to future large space facilities. Progress 41 docked with the station on March 18. On April 10, its engines were used to boost Mir's orbit. The maneuver was one of many mothballing procedures the crew undertook in its last days aboard Mir. The April crew exchange mission was cancelled because a scheduled modular addition to Mir was delayed. For the first time in 27 months, Mir would be left unattended. Progress 41 undocked on April 21 and reentered April 25 after five days of autonomous flight. At 23:28, April 26, Soyuz TM-7 undocked from the space complex with Volkov, Krikalev and Polyakov aboard. Polyakov had been in space since August 29, 1988; Volkov and Krikalev since November 26, 1988. The long-duration crew landed in the Soviet Union at 02:59, April 27.

TM-8

Alexander Viktorenko and Alexander Serebrov were launched 21:38, September 5 from the Baikonur Cosmodrome aboard Soyuz TM-8. Their arrival at Mir, September 7, was preceded by a new class Progress supply vehicle. Progress M-1 (see below) docked with the front axial port of the Soviet space station August 25. Soyuz TM-8 berthed at the aft port two weeks later. Because of a misalignment on approach, automatic docking was aborted; the cosmonauts manually guided the 7,150-kg transport the last few meters to the docking unit, completing the connection at 22:25. After reactivating the dormant station, Viktorenko and Serebrov spent their first weeks on orbit making stellar observations and performing microgravity experiments. Preparing for the next modular addition to the

complex, they replaced Mir's computer memory with an upgraded version accounting for the mass of an expanded station — data required for accurate maneuvers. The first of two planned building blocks, Kvant 2 (see below), arrived December 6, docking with the port vacated a week earlier by Progress M-1. On the 12th, the crew backed Soyuz TM-8 away from Mir's aft port. The station was rotated 180 deg., allowing Soyuz to redock at the forward port, making room at the rear for Progress M-2. The year's last resupply ship docked December 22. Onboard was a U.S. microgravity experiment, which was activated December 25. Mir's first U.S. payload is slated to operate for three months.

Progress M-1, M-2

An improved version of cargo freighters used to supply the Mir space station, the Progress M series has greater cargo capacity, a modernized approach/docking system and carries two solar panels to generate electrical power. Progress M can fly for 30 days independently and 108 days docked with Mir. Spare propellent in Progress M's tanks can be transferred to Mir before it is consigned to burn up in reentry. In the past, extra fuel was abandoned with the craft. Future Progress vehicles will carry a recoverable reentry capsule for the speedy return of up to 150 kg of material from Mir to earth. The Progess M vehicles were launched from Tyuratam aboard Soyuz (A-2) boosters. Progress M-1 was launched August 23, 1989 at 03:10. Progress M-2, at 03:31, December 20.

Kvant 2

Kvant 2, the first of two expansion modules planned to enlarge the Mir space complex in the near term, arrived at the station December 6 at 12:21. The three-section addition, originally called Module D, was launched from Tyuratam at 13:01, November 26, via a three-stage Proton (D-1) booster. It was originally scheduled to dock December 2, but was delayed by technical problems. The new module successfully docked at Mir's front axial port at 12:21, December 6. Two days later, a Liappa docking arm re-docked the module at the upper radial port. Kvant 2 weighed 19,565 kg at launch. A cylinder, it measures 13.73 m long and 4.35 m maximum diameter. Two 26.6-sq-m solar panels provide 6.9 kW of power. The module is divided into a service/cargo section, a payload/equipment section and an airlock permitting easy exit and entrance to Mir during EVAs. Kvant 2 carried an East German multi-spectral remote sensing camera and an Ikar ("Icarus") manned maneuvering unit. The unit will be tested in 1990. The next building block, a technology module, is scheduled to arrive in Spring 1990. Kvant 1, the first Mir expansion, docked in April 1987.

Ulysses, courtesy of JPL

New Spacecraft to Observe the Sun

by Phillip S. Clark

If all goes well in October 1990, the European Ulysses solar probe will be launched towards Jupiter by a space shuttle mission. At present this is the only budgeted spacecraft to be launched into orbit around the sun to specifically study our nearest star.

The Soviets, however, have been talking about a solar close approach mission since 1987. Now named Tsiolkovski, the Soviet launch could come in the mid-1990s. The Jet Propulsion Laboratory has a Solar Probe mission under study; and, budgets permitting, the United States could launch a new Orbiting Solar Laboratory in the mid-1990s. With these missions—all looking at the sun from different orbits—we could vastly increase our knowledge of solar activity.

The Ulysses Story

When originally planned in the 1970s, the Out of the Ecliptic (OOE) mission comprised two spacecraft. One craft would be built by the European Space Agency and the other by NASA. Each craft would perform passes over the solar poles, thus allowing the first investigations of the sun to be completed from above the ecliptic plane (hence the name). The two craft would be shuttle-launched towards Jupiter. By passing over opposite jovian poles, they could be redirected to fly over opposite poles of the sun at a distance of some 250 million km, four years after launch. The mission called for a single launch of both payloads, using a three-stage IUS, in February 1983.

In 1980, NASA decided against developing the three-stage IUS, thus raising doubts about both craft being launched on one shuttle flight. The flight had already been delayed until the 1985 launch opportunity when, in 1981, budget cuts forced NASA to cancel its spacecraft. ESA was left with only half a mission. It was agreed, however, that NASA would provide the launch facilities using the shuttle, as well as tracking service and the radioisotope thermoelectric generator. Additionally, there would be collaboration between the U.S. and ESA in the experiments flown on the spacecraft. Instead of an IUS, a Centaur upper stage would be used for heliocentric orbit injection.

OOE had been renamed the International Solar Polar Mission (ISPM) but was finally given the name Ulysses, honoring Homer's hero and referring to Dante's description of Ulysses' urge to explore an "uninhabited world

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behind the sun." Further delays in the shuttle program postponed the scheduled launch until May 1986, the same window as the Galileo Jupiter mission. The loss of the Challenger in 1986 delayed the mission again.

In April 1987, an agreement was signed between ESA and NASA which guaranteed a priority launch for Ulysses during the October 1990 launch opportunity, after the October 1989 launch window had been assigned to Galileo. With the post-Challenger safety regulations, the Centaur was deleted. A two-stage IUS will now be used, with a PAM-S providing the extra acceleration to reach a trans-Jupiter orbit.

A Launch at Last

At the time of writing, the Ulysses launch is scheduled for the STS 41/Atlantis mission (October 1990). This will allow Ulysses to swing by Jupiter's north pole in February 1992. The first solar polar passage will be during May 31 - October 6, 1994, when the spacecraft will be below solar latitude 70 deg. s; the second will take place May 30 - September 16, 1995, above 70 deg. n. Flyby distances will be about 250 million km and will coincide with the period of solar maximum activity.

Ulysses has an initial mass of 371 kg, including the stage adapter, and is powered by a single radioisotope thermoelectric generator which will provide 260 W of power towards the end of the mission. The onboard experiments and responsible countries are:

- Solar Wind Plasma: two electrostatic analyzers with channel electron multipliers (U.S.)
- Solar Wind Ion Composition: electrostatic analyzer with time-of-flight and energy measurements (U.S. and Switzerland)
- Magnetic Fields: triaxial vector helium and fluxgate magnetometers (UK)
- Energetic Particle Composition and Neutral Gas: four solid-state detectors (FRG)
- Low Energy Charged Particle Composition and Anisotropy: two sensor heads with five solid-state detectors (U.S.)
- Cosmic Rays and Solar Particles: five solid-state detectors (U.S.)
- Radio and Plasma waves: 72-m radial dipole and 8-m axial monopole antennas with 2- axis search coil (U.S.)

- ❑ Solar X-rays and Cosmic Ray Bursts: two silicon and two caesium iodide detectors (France & FRG)

- ❑ Cosmic Dust: multicoincidence impact detector with channeltron (FRG).

In addition, the Ulysses radio system will allow for coronal sounding (FRG) and gravitational wave investigations (Italy). Similarly, other instruments will provide data for solar wind directional discontinuities (Belgium) and solar wind mass loss ion composition (Italy).

After launch, Ulysses will be spin-stablized at five rpm, the main antenna pointing continuously at earth. It will be tracked for eight hours each day by the 34-m dishes of NASA's Deep Space Network. Operations will be conducted by ESA specialists based at the Jet Propulsion Laboratory's (JPL) Mission Control and Computing Center.

Solar Probe Studies

The Jet Propulsion Laboratory is currently studying a close-approach solar spacecraft. Initially called Starprobe, it has been renamed Solar Probe.

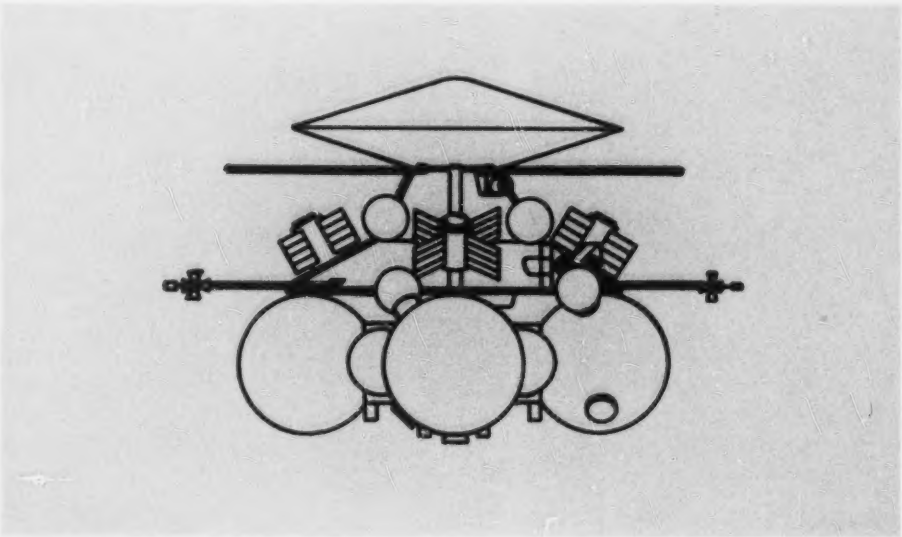
This would not be the first spacecraft sent towards the sun. The two FRG Helios spacecraft (launched in 1974 and 1976) paved the way, passing within 50 million km of the sun (Helios 2 passed closest, at about 45 million km) without the advantage of a Jupiter flyby. The Solar Probe, however, would pass far closer to the sun, skimming some 3 million km from the surface.

The Solar Probe concept calls for a 1,200-kg, 4-m by 11-m spacecraft, probably launched aboard the space shuttle. Like Ulysses, Solar Probe would be launched towards Jupiter to gain energy at planetary encounter for the orbital change, allowing a close flyby of the sun. During the flyby, the spacecraft would study the corona, chromosphere and photosphere at a resolution of 10 km in the visible to X-ray wavelengths.

The Soviet Corona Proposal

At the Space Futures Forum, held in Moscow in October 1987 (celebrating the 30th anniversary of Sputnik 1), the Space Research Institute and the USSR Academy of Sciences revealed plans for Solar System exploration with unmanned spacecraft through the turn of the century. Realistically, the missions discussed could not all be funded by the Soviets alone, and the call was made for extensive international collaboration. Even if such collaboration were forthcoming, it is hard to imagine all of the missions being undertaken.

The brochure issued by the Space Research Institute at the time noted the possibility of launching Corona spacecraft in 1995. The spacecraft would fly by Jupiter and then swing in toward the sun, passing as close as 5 to 7 solar radii (3.5-4.9 million km). Few other comments were made later about the mission and it was thought it might have been quietly dropped — due in part to budgetary problems and because it would be so technically demanding. Surprisingly, at the October 1989 International Astronautical Federation Congress, the mission seemingly reappeared, but under another name.



Solar Probe *Drawing by Daniel Gauthier*

Soviet Tsiolkovski Missions

It is unclear whether the proposed Tsiolkovski mission is a renamed Corona mission or whether it is new. Tsiolkovski is planned as a series of spacecraft, launched to investigate the sun from close quarters, although the October 1989 discussions gave details on only the first such mission.

The first launch could come as early as 1996, and would use a four-stage Proton booster plus a spacecraft propulsion system for trans-Jupiter orbital injection. The launch profile would be similar to that employed for the 1988 Phobos missions. Initially the first three stages of the Proton would orbit the combined Block-DM stage, propulsion system and spacecraft into low-earth orbit (total mass about 20 metric tons). The Block-DM would burn to depletion, leaving the propulsion system and spacecraft in an eccentric earth orbit; the propulsion system would then ignite to place the spacecraft on a trans-Jupiter trajectory. The propulsion system could carry up to 3.1 metric tons of fuel, depending upon mission requirements.

A launch like this could propel a total spacecraft mass of up to 2.1 metric tons towards Jupiter, although the IAF information looked specifically at a mission with a total mass of 1.2 metric tons.

Each Tsiolkovski mission would comprise two spacecraft: the orbital module would have a mass of up to 740 kg, and carry a science payload of 40 kg; the solar probe would be 460 kg, with 60 kg of experiments. On later missions, the probe could have a mass of 900 to 1,200 kg. A special science platform with a mass of up to 1.3 metric tons is a possible addition to the orbital module.

The Soviets view the mission in two parts: operations from launch until solar approach, and solar probe deployment for the major investigations at perihelion. The orbital module would be responsible for all operations until 10 days before perihelion; the probe would then separate for the main research tasks. Presumably, the orbital module would not be protected against the intense solar radiation, unlike the probe. The orbiter would, because of the flight out to Jupiter, carry radioisotope generators for power. The probe could rely on chemical batteries for its relatively short mission.

It remains to be seen whether the Tsiolokovski mission will be attempted this century. As already noted, the technical difficulties are immense and the Soviet 1996 launch date is considered highly optimistic.

Orbiting Solar Laboratory

Unlike the Soviet and JPL-proposed missions, NASA's Orbiting Solar Laboratory (OSL) would not fly close to the sun to obtain information. Its observations would be made from earth orbit. Under consideration for a 1996 launch, OSL would enter a circular 510 km, 97.4 degree sun-synchronous orbit. The spacecraft mass would be about 3.4 metric tons, suitable for a Delta II class launch.

Although OSL's orbit is sun-synchronous, OSL would not observe the sun continuously. Continuous observations would be made for two months each year, less detailed coverage for the rest of the time. This pattern permits the observatory to study evolving solar activity and rare solar events. While the OSL mission is proposed as a three-year endeavor, it is anticipated that the spacecraft could actually operate for about eight years.

Research conducted via OSL would be coordinated with the efforts of the international Solar Terrestrial Physics program and the Earth Observing System (EOS). For the first time, observations could be made simultaneously from space and ground-based solar telescopes. OSL data can be distributed directly to participating international institutions and observatories for analysis. The proposed instrument packages include:

- Coordinated Instrument Package (CIP): comprising a photometric filtergraph (California Institute of Technology); tunable filtergraph/ magnetograph (Lockheed Palo Alto Research Laboratory); white light spectrograph (Kiepenheuer Solar Institute, FRG); and CIP correlation tracker

- High Resolution Telescope and Spectrograph (HRTS): comprising a Gregorian telescope; spectrograph; spectroheliograph; and H-alpha camera (Naval Research Laboratory)

- XUV/X-ray Imager (XXI): comprising normal incidence optics; and multilayer narrow bandpass filters (Italian Space Agency and USAF Geophysical Laboratory).

The OSL instruments will allow a spatial resolution never before possible in the visible, ultraviolet and soft X-ray wavelengths. The high resolution capability will permit the observation and correlation of solar activity both at the surface and in the solar corona, as well as studies of the solar ultraviolet phenomena that control the formation of the terrestrial ozone layer, thus affecting conditions on the earth's surface and its climate.

The sun's effect on earth's day-to-day and long-term weather and radiation systems is just one reason that such solar missions as OSL, Solar Probe, Tsiolokovski and Ulysses are important. Because the sun is the nearest star, it is the only one that earthbound scientists can study in detail over the foreseeable future. As manned space flights begin to venture farther afield, the ability to accurately forecast solar activity will become more critical. The solar exploration missions that are being flown and proposed for the 1990s will greatly expand our knowledge of the sun and its influence on our environment.

Table 1. Dedicated Solar Spacecraft in Heliocentric Orbit

Launch Date	Name	Mass kg	Incl[1] deg	Period days	Perihelion AU[2]	Aphelion AU	Launch Vehicle
1960 Mar 11	Pioneer 5	43	3.35	312	0.806	0.992	Thor Able
1965 Dec 16	Pioneer 6	64	0.17	311	0.814	0.985	Thor Delta
1966 Aug 17	Pioneer 7	64	0.10	403	1.012	1.125	Thor Delta
1967 Dec 13	Pioneer 8	66	0.06	386	0.990	1.087	Thor Delta
1978 Nov 8	Pioneer 9	66	0.09	298	0.756	0.990	Thor Delta
1969 Aug 27	Pioneer E	67	Launch failure				Thor Delta
1974 Dec 10	Helios 1	370	0	190	0.307	0.985	Titan III/ Centaur
1976 Jan 15	Helios 2	376	0	186	0.28	0.995	Titan III/ Centaur
1978 Aug 12	ISEE 3[3]	479	Initially located at Sun-Earth/Moon libration point				Delta

Table lists spacecraft specifically launched for solar studies; it excludes many interplanetary missions that conducted solar studies enroute to their main targets. Helios 1 and 2 were launched for Federal Republic of Germany; Pioneers, ISEE 3 were U.S. missions.

[1]Orbital inclinations refer to the plane of the ecliptic
[2]Astronomical Unit, approximately 149,600,000 km
[3]International Sun-Earth Explorer, renamed International Cometary Explorer (ICE) after it was retargeted to rendezvous with Comet Giacobini-Zinner in 1985.

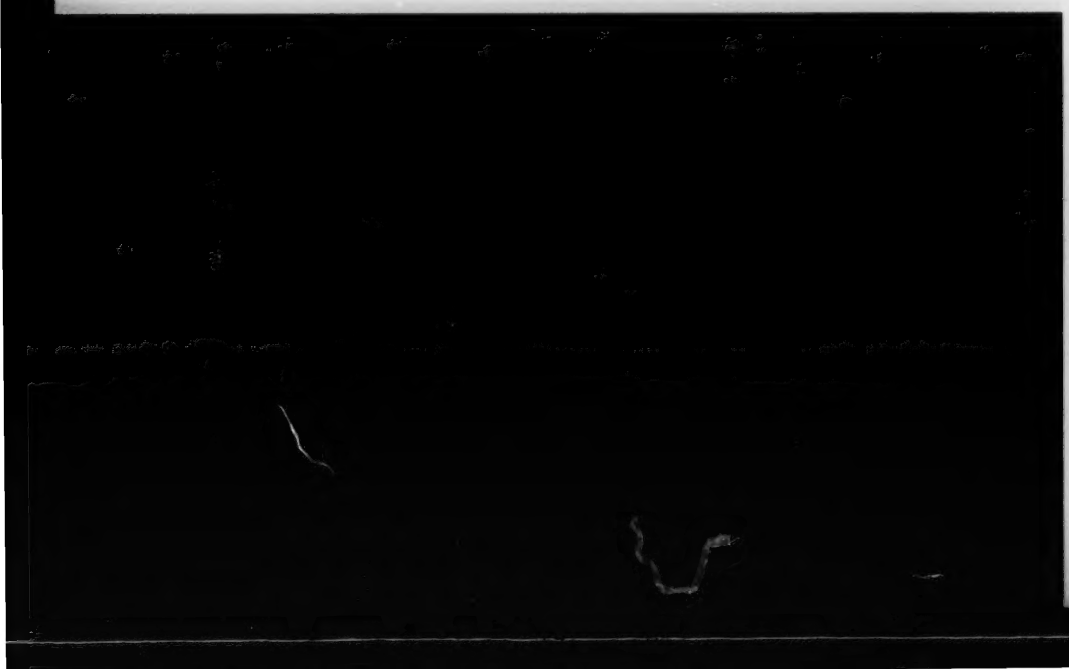
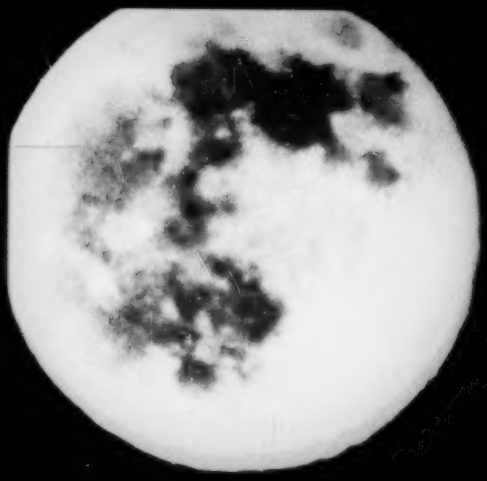


Table 2. Earth Orbiting Solar Observatories

Launch Date	Satellite	Mass (kg)	Incl (deg)	Period (mn)	Perigee (km)	Apogee (km)	Launch Vehicle
1962 Mar 7	OSO 1	208	32.8	96.0	553	595	Delta (U.S.)
Apr 26	Solrad 4B	91	Launch failure				Scout (U.S.)
1965 Feb 3	OSO 2	247	32.9	96.4	550	634	Delta (U.S.)
Aug 25	OSO C	280	Launch failure				Delta (U.S.)
1967 Mar 8	OSO 3	281	32.9	95.5	534	564	Delta (U.S.)
Jun 16	Kosmos 166	357	48.4	92.8	281	553	B-1 (USSR)
Oct 16	OSO 4	272	33.0	95.6	546	560	Delta (U.S.)
1968 Jul 5	Kosmos 230	367	48.4	92.7	285	543	B-1 (USSR)
1969 Jan 22	OSO 5	291	32.9	95.5	536	561	Delta (U.S.)
Aug 9	OSO 6	290	33.0	94.9	491	554	Delta (U.S.)
Oct 14	Interkosmos 1	320	48.4	93.3	254	626	B-1 (USSR)
1970 Oct 14	Interkosmos 4	320	48.4	93.6	255	648	B-1 (USSR)
1971 Sep 29	OSO 7	635	33.1	93.4	323	571	Delta (U.S.)
1972 Apr 14	Prognoz 1	845	65.0	5,782.1	1,005	199,667	A-2-e (USSR)
Jun 29	Prognoz 2	845	65.3	5,849.2	517	201,804	A-2-e (USSR)
Jun 30	Interkosmos 7	375	48.4	92.6	260	551	B-1 (USSR)
1973 Feb 15	Prognoz 3	845	65.0	5,783.0	590	200,000	A-2-e (USSR)
Apr 19	Interkosmos 9	400	48.4	102.1	199	1,526	B-1 (USSR)
May 14	Skylab/ATM	11,180	50.0	93.2	427	439	Saturn 5 (U.S.)
1974 May 17	Interkosmos 11	400	50.6	94.5	483	591	C-1 (USSR)
Dec 26	Salyut 4/OST-1	18,900	51.6	91.3	336	349	D-1 (USSR)

1975 Jun 3	Interkosmos	350	Launch failure				C-1 (USSR)
Jun 21	OSO 8	1,064	32.9	95.5	544	560	Delta (U.S.)
Dec 22	Prognoz 4	905	65.0	5,740.0	634	199,000	A-2-e (USSR)
1976 Mar 15	Solrad 11A	181	25.7	7,344.3	118,383	119,180	Titan IIIC (U.S.)
	Solrad 11B	181	25.6	7,116.7	115,720	116,645	Titan IIIC (U.S.)
Jul 27	Interkosmos 16	550	50.6	94.4	464	517	C-1 (USSR)
Nov 25	Prognoz 5	930	65.2	5,728.0	777	198,560	A-2-e (USSR)
1977 Sep 22	Prognoz 6	910	65.0	5,688.0	488	197,867	A-2-e (USSR)
Sep 24	Interkosmos 17	550	83.0	94.4	466	514	C-1 (USSR)
Oct 22	ISEE 1	340	28.9	3,440.9	337	137,904	Delta (U.S.)
	ISEE 2	166	29.0	3,439.1	341	137,847	Delta (U.S.)
1978 Oct 30	Prognoz 7	950	64.9	5,881.1	472	202,627	A-2-e (USSR)
1979 Feb 24	Solwind	1,311	97.6	96.4	563	602	Atlas (U.S.)
1980 Feb 14	Solar Max	2,315	28.5	95.9	566	569	Delta (U.S.)
Dec 25	Prognoz 8	910	65.8	5,689.0	980	197,390	A-2-e (USSR)
1981 Sep 19	Shi Jian 2	257	59.5	103.4	234	1,610	FB-1 (China)
Oct 6	Solar Mesosphere Explorer	437	97.5	95.5	538	542	Delta (U.S.)
1983 Jul 1	Prognoz 9	1,060	65.5	3,8448.0	380	720,000	A-2-e (USSR)
1985 Apr 26	Prognoz 10	1,000	65.0	5,785.1	421	200,320	A-2-e (USSR)
Jul 19	Spacelab 2	15,034	49.5	90.9	312	320	Challenger/STS-19 (U.S.)

The table lists launches intended primarily for solar research, excluding many missions that conducted solar studies as well as other experiments. The Skylab Apollo Telescope Mount (ATM) and Salyut 4 OST-1 (Orbiting Solar Telescope) were major space station experiments, while Spacelab 2 was dedicated to solar research.



The Fast Track on Orbital Traffic

The hollowed halls of the mountain house the military centers which provide early airborne, missile and space threat warning to the U.S. and Canada. The North American Aerospace Defense Command (NORAD) and the U.S. Space Command (USSPACECOM), composed of the Air Force, Navy and Army Space Commands, are the responsible agencies. The SSC conducts space surveillance operations in support of the USSPACECOM space control and warning missions.

The SSC is the focal point for space surveillance, chartered to verify new launches, monitor satellite positions and breakups, predict decays and provide orbital information to military and government agencies. Its latter responsibility, bestowed by a 1961 Congressional mandate, makes SSC the unofficial clearinghouse for orbital data used by space watchers worldwide. NASA Goddard Space Flight Center receives SSC's computations and, in turn, provides the unclassified information to civilian users. Most orbital data published and used around the globe (including Space Log) originated at USSPACECOM or is derived from its element sets.

Elset Signatures

Element sets or "elsets,"* the unique mathematical signatures of orbiting bodies, are kept current for every known man-made object in earth orbit. They have to be. Elsets define an object's orbit, showing where it was at a given time and allowing analysts to predict where it will be in the future. They are the best, and sometimes only, means of recognition. Elsets enable orbital analysts to identify maneuvering space objects, associate the flotsam of spaceborne explosions with known rocket bodies and give ground-based sensor sites the look angles (azimuth and elevation) needed to locate objects of immediate interest. Without current elsets, the whereabouts and identities of catalogued objects would eventually be lost to dark and distant space.

Today earth's space environment hosts some 6,900 objects — 1,850 of them payloads. Monitoring them is a massive task made manageable by an automated computer system and five eight-person (five from USSPACECOM, three from Air Force Space Command) crews who keep the

*The NORAD two-line element set consists of: right ascension of ascending node, inclination, mean motion, first derivative of mean motion (speed), second derivative of mean motion (acceleration), mean anomaly (how far from perigee), eccentricity, coefficient of drag, epoch time, argument of perigee.

SSC up and running 24 hours a day; seven days a week. Each artificial satellite remains under the twice-daily watch of a worldwide network of radar and optical sensors. The sensors dispatch detection data directly to the SSC, where observations are compared with the predicted locations of catalogued objects. The sensors "see" and report after satellites have maneuvered, or after orbits have changed due to drag or solar activity. Observed information that cannot be verified or matched often represents a new object. When a new object is found, its approximate orbit is determined by orbital analysts, who identify it and assign it the next sequential catalog number.

"New" objects are not necessarily new launches. While the sensor network makes some 30,000 to 50,000 observations each day, it doesn't see everything. Some debris is too small to be detected. Optical sensors are limited to darkness or clear weather; radars typically have a narrow field of view. Small fragments from exploding rocket bodies, for example, may escape initial detection only to be found weeks, months or even years later. Debris from the Transit 4A rocket body, which exploded in 1961, is still being found, identified and catalogued 27 years after the fact. Many of these previously unseen objects are spotted as they drift down from higher orbits. Small fragments are ultimately detected as sensor system sensitivity is improved.

Found Fragments

Identifying old fragments is the province of NAVSPACECOM's Naval Space Surveillance System, headquartered in Dahlgren, Virginia. The East Coast Naval facility, which also serves as the SSC backup, spends one day a week sorting and cataloguing debris associated with previous break ups.

When a group of new bodies is detected, as was the case when an Ariane rocket unexpectedly exploded in 1986, Cheyenne Mountain analysts determine the elsets of the resulting fragments and the point where the new objects mathematically intersect. The elset at the point of intersection defines where the original object broke up. By determining, again from elsets, what object should have occupied that position at that time, analysts can identify the fragment source. If the SSC computer cannot verify that data, analysts must perform additional calculations to discover the likely source of the debris. Unidentifiable objects are relegated to a separate catalog — fodder for Dahlgren analysts.

Some tiny debris — smaller than a basketball in high orbits, a baseball in low-earth orbit — may go unnoticed entirely. Exceptions are small items whose vital elsets are known. In the past, such inadvertently orbited items as a Hasselblad camera, astronaut's glove and shuttle-borne wrench were routinely tracked until they decayed.

	SATELLITE NO.	INTERNATIONAL DESIGNATOR	EPOCH
LINE 1	1 202970	89 84	A 89291.73333059
LINE 2	2 20297	34.3150	148.5416 0006349

	INCLINATION	RIGHT ASCENSION OF THE ASCENDING NODE	ECCENTRICITY

2-Line Element Set for Atlantis Space Shuttle (STS-34)

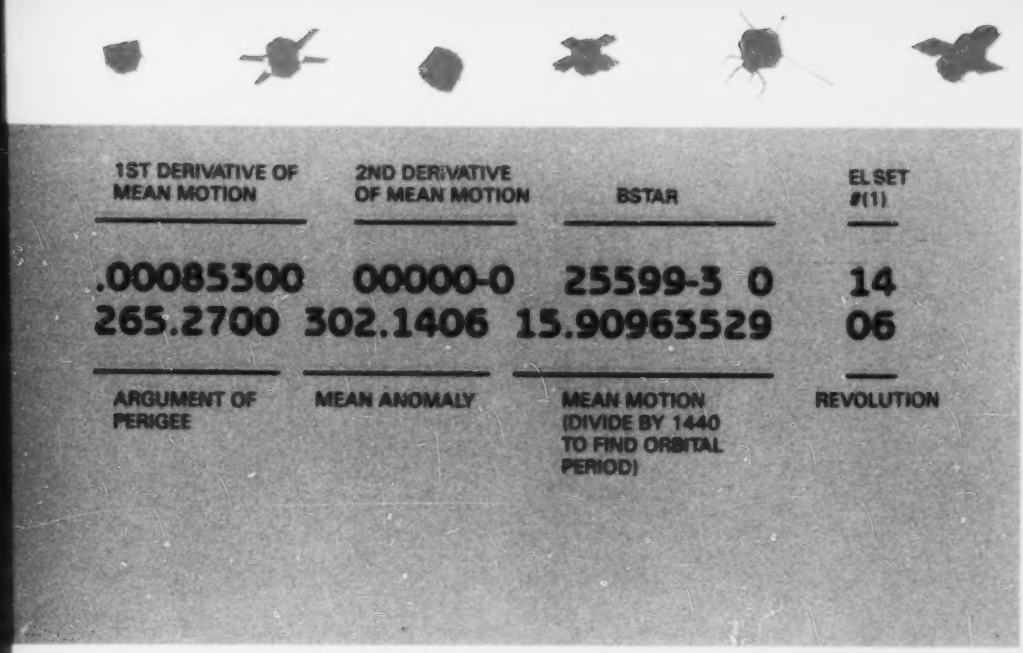
At any given time, some 10 to 20 space objects are decaying to the point where reentry is imminent. Rocket bodies and platforms may reenter within hours of launch. Items in higher orbits will take longer. A 1967 United Nations treaty stipulates that launching countries are responsible for damage caused by reentering space vehicles. SSC is, therefore, charged with predicting reentry time and approximate location for bodies large enough to possibly survive the heat of reentry. The first Tracking and Impact Prediction (TIP) report for a decaying object is generated two weeks in advance of its forecasted reentry. A second calculation is done four days before, then two, then one, then at 12 hours, six hours and finally two hours before the decaying body reenters earth's atmosphere. High reentry speeds — some 480 km a minute — limit location predictions; timewise, SSC is generally accurate within 15 minutes.

Routine Reentries

Most reentries are routine, occurring without fanfare. The 1988 reentry of Kosmos 1900 is a rare exception, attracting world notice only because of its nuclear power source.*

The remaining 884 uncontrolled reentries that year were largely ignored. Of those, 768 were small fragments, 26 were payloads and 90 were large rocket bodies. In general, less than 10 percent of large bodies survive reentry, and of those, most land in the ocean or remote areas. Skylab's her-

*Kosmos 1900's nuclear reactor was ejected into a higher orbit before the satellite burned up in the atmosphere October 1.



alded reentry in 1979 also garnered world attention, but it too landed out of harm's way.

While 900-plus space objects decayed in 1988 (40 were controlled reentries), the congregation of man-made orbiters is continually replenished by new breakups and launches. New launches are sighted by the sensor network almost immediately. Once a launch heading has been derived from initial detection data, SSC tasks the sensors down the line to track it. When the payload reaches orbit, analysts create a mathematical model of its path in space — the vehicle's vital elsets.The same model is created for attendant rocket bodies or platforms that stay aloft. The new orbiters are assigned international designator and catalog numbers and become part of the permanent inventory.

The inventory of "non-routine" or "special event" satellites, i.e. new launches, decays, operational satellites and those expected to maneuver are individually tracked by Air Force, Navy and Army personnel staffing USSPACECOM's SSC. The men and women of the mountain monitor some 200 non-routine orbiters at any given time. They direct the sensor sites to look for specific objects of interest and a steady stream of observations flows in from around the world. SSC's computer supplies constantly updated data to orbital analysts, who may monitor an object's status hour by hour or less.

Routine monitoring of the remaining 6,700-plus space objects falls to the Air Force Space Command. AFSPACECOM personnel, colocated in SSC, also keep the satellite catalog of known objects current.

Photo courtesy of Roger Berg

Automatic Updates

Sheer volume dictates that routine updates be handled automatically. Incoming sensor data for catalogued objects is computer analyzed. When a predetermined threshold of orbital change is exceeded, the elsets for a given item are updated. The computer also calculates classical orbital data—perigee, apogee, inclination, period—based on current elsets. Revised data is supplied every 24 hours for most objects, up to 30 days for some high altitude bodies in stable orbits.

With so much traffic circling the globe, launching agencies are understandably concerned about possible collisions in space. USSPACECOM's comprehensive knowledge base allows it to provide collision avoidance support for NASA manned missions. Using a Computation of Miss Between Orbits (COMBO) program,* orbital analysts identify objects that may interfere with a shuttle orbit, defining how close in kilometers they will come. If any objects threaten the projected mission, NASA can make

*COMBO can also be used to define spacecraft maneuvers and to find satellites temporarily "lost" when their orbits are unpredictably altered by solar flares or other phenomenon.

preventative changes. As a result, there have been no close calls or near misses, save for the fleck of red paint that hit a window on STS-7 in 1983. The paint chip was far too small to be observed by USSPACECOM's sophisticated tracking system.

Could paint chips be discerned by the system, they too would become part of the SSC satellite catalog; that is, if their tracks could be correlated. No object is catalogued unless USSPACECOM is confident it can be reliably tracked. An object must be seen twice by a single sensor on consecutive passes, or by any two sensors worldwide before it is added to the inventory of known orbiters.

This inventory, identified by up-to-date elsets, comprises a unique celestial map of sorts—a field of artificial satellites mathematically charted by USSPACECOM's subterranean space surveillance center. In some ways, the best view of the heavens is from 520 meters underground.

Voyager/Neptune: Picture Perfect

At 03:56, August 25, the 12-year-old Voyager 2 spacecraft skimmed 4,500 km over the cloud tops of Neptune, at that time the solar system's outermost planet. It was the final planetary point of call on a sweeping grand tour that had taken the 825-kg spacecraft by Jupiter, Saturn and Uranus. Four hrs 6 mns after Voyager's closest approach, the data stream of images taken of Neptune's atmospheric surface began arriving at the Jet Propulsion Laboratory in Pasadena, California. By then the spacecraft, traveling at 98,116 km per hour, was nearing its 39,800-km brush by Triton, soon after to leave the solar system behind.

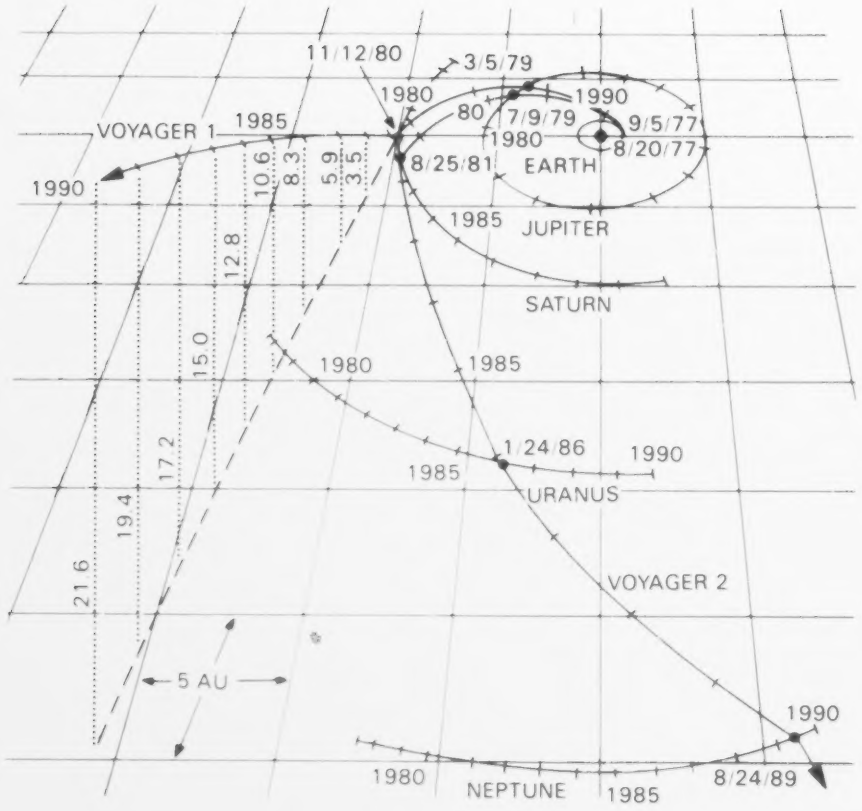
Voyager's close approach at Neptune, culminating a 7 billion km journey, came within 32 km of target and within 1.4 seconds of schedule. The aging spacecraft, laden with 10 scientific experiments, two "antique" Vidicon cameras and an obsolete computer with less memory than today's desktop computers, did not let outdated technology or the 4.3 billion km chasm separating it from earth disrupt its discovery mission.

Its first news from the distant world arrived in mid-June, two weeks after the mission observatory phase began. A suspected new moon, appearing as a light speck in early images, was confirmed July 5. Subsequent images showed the new moon, 1989 N1, to be about 400 km in diameter — larger than the irregularly shaped Nereid. At 340 km diameter, Nereid was demoted to Neptune's third largest satellite.

By encounter's end Voyager added five more moons ranging from 54 km to 190 km diameter, and four rings to the body of Neptunian knowledge. The rings, only portions of which had been viewed from earth, were previously thought to be ring arcs. Instead Voyager found very faint, but complete rings, the outermost — 62,900 km from the planet — contains three optically thicker arcs, which may explain earth-based observations.

Voyager found the cool blue planet more active than anticipated, awash with 1,100-km-per-hour winds, an earth-sized storm center, and cirrus-like clouds scuttling 80-120 km above the dense atmosphere. While hydrogen is the dominant atmospheric constituent, an abundance of methane, which absorbs red light, gives Neptune its blue appearance.

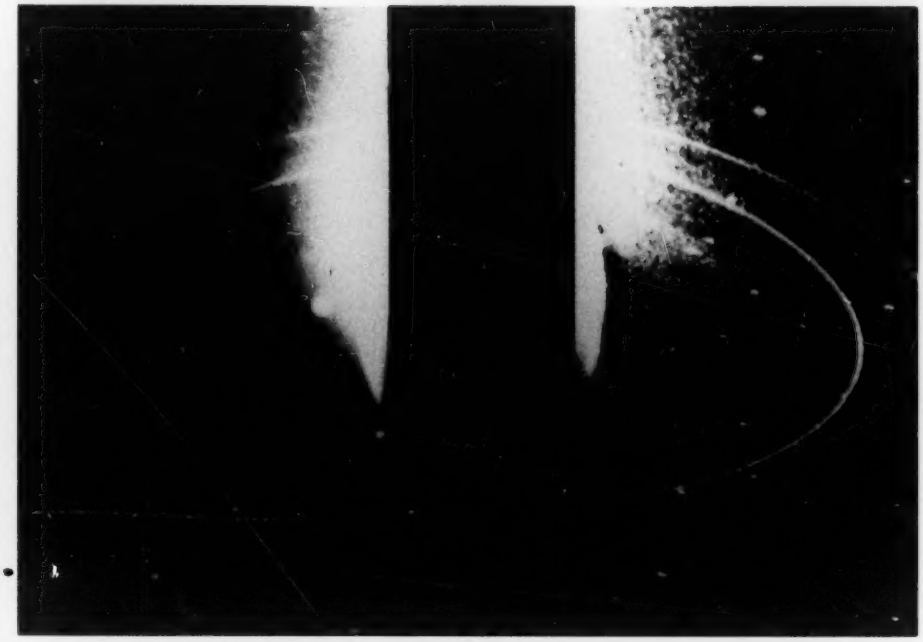
The magnetic field was first encountered some 470 Neptune radii out from the planet. Voyager crossed the bow shock at 34.9 Neptune radii. Closer in, the magnetic field rotates with the planet every 16.11 hrs and was found tilted 46.8 degrees.



Voyager 2 was launched August 20, 1977, on a sweeping trajectory taking advantage of a planetary alignment that occurs once every 175 years. The spacecraft flew by Jupiter in July 1979, Saturn in August 1981, and Uranus in January 1986.

Observations made during Voyager's 09:10, August 25 appointment with Triton and the eight hours following showed Neptune's largest moon, with a 2,705 km diameter, to be smaller than predicted. Stained pink from photochemical interactions, it is capped with thin blue layers of methane frost. At 400 degrees F below zero, Triton is the coldest known body in the solar system. Its entire surface is covered with methane and nitrogen ice. Data collected during the swingby apparently validated theories that the moon, which orbits in the opposite direction of Neptune's rotation, was captured by the planet's gravity.

The rich harvest of data did not end with Voyager's exit from the Neptune system. Much of the data was stored for later transmission. The radio science experiment alone generated 450 kg of magnetic tape. Just days before the

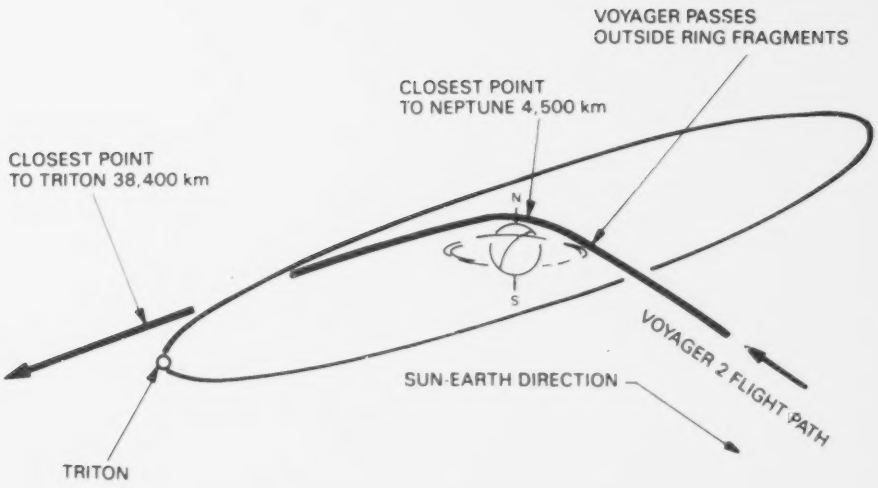


Two post-flyby 591-second exposures by Voyager's wide angle camera capture Neptune's narrow, bright rings and the faint broad ring nearest the planet. A second broad band is barely discernible between the outer rings.

encounter period officially ended on October 2, investigators discovered a geyserlike plume erupting on Triton. The apparent nitrogen ice "volcano," found in one of the 8,000 images dispatched during the encounter period, affirmed suspicions that dark 40-km long features on Triton were created by surface eruptions.

While the imaging equipment provided the most breathtaking scientific returns, many of Neptune's secrets were revealed by a cast of scientific instruments measuring and detecting thermal energy, reflected light, atmospheric composition, temperature, trapped electrons, charged particles, the magnetosphere, electric field and radio emissions and magnetic fields.

Voyager's enduring success has been squeezed from a series of earth-based technology improvements. Following the 1986 Uranus encounter, the three largest antennas of NASA's Deep Space Network were enlarged from 64 to 70 m. Receiver capability was strengthened with supercooled low-noise amplifiers, allowing Voyager's signal — about one ten-quadrillionth of a watt — to come in louder and clearer. As at Uranus, the DSN antennas were electronically linked, allowing more spacecraft signal to be captured. Japan's 64-m Usuda radio antenna supported critical radio science observations during closest approach. All together, 38 antennas worldwide received Voyager data.



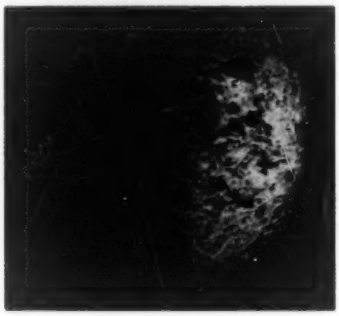
Voyager's flyby trajectory took it past Neptune's north polar region where gravity bent its flight-path some 45 degrees towards Triton. The spacecraft's 4,500-km swing by Neptune was the closest approach of the planetary grand tour.

The onboard computer command subsystem was programmed with stored responses to anticipated problems. Thus, the spacecraft could act autonomously if need be. The 8 hr, 12 mn round-trip communications time delay would not hamper the mission or Voyager's ability to perform.

The spacecraft has been reprogrammed several times over the years to better acquire, process and send data. Onboard computers have been customized to gather, compress and return as much information as possible. Required error coding was reduced, providing more room for science data. Compression techniques reduced image data bit volume by 60 to 70 percent. Despite being 1.6 billion km farther from earth at Neptune than at Uranus, Voyager matched its previous encounter transmission speed of 21.6 kilobits per second.

Because Neptune receives about one thousand times less sunlight than earth, Voyager's camera shutter had to remain open on average from about 15 to 96 seconds. Those long exposures, coupled with spacecraft motion, could have smeared the images. To prevent that, the scan platform was commanded to track the target while the spacecraft attitude remained static. The technique — maneuverless image motion compensation — was augmented by reduced thruster firings for attitude compensation. Firings were reduced from 10 to 4 milliseconds.

About 56 million km beyond Neptune, Voyager's instruments were quieted, conserving energy for the long odyssey ahead. In February 1990, Voyager's cameras were pointed back towards the sun, taking the first in a series of planetary photos that will be compiled into a solar system "family portrait." Voyager 2 continues into interstellar space, now seeking signs of the outer boundary of the heliopause, the point where the sun's influence ends and interstellar space begins. Communications are expected to continue for another 25 years.



Box Score of U.S. Launches

Worldwide record of known successful U.S. launches

International payloads are listed when launched by U.S. booster

Classified U.S. payloads are listed by launch vehicle

*Payload(s) injected into orbit

1957

Vanguard TV 3

*Successes: 0
Failures: 1
Total: 1

1958

Score
Pioneer 3
Pioneer 1
Explorer 4
Explorer 3
Vanguard 1
Explorer 1

Pioneer 2
Beacon 1
Vanguard SLV 3
Explorer 5
Able 1
Vanguard SLV 2
Vanguard SLV 1
Vanguard TV 5
Explorer 2
Vanguard TV 3A

*Successes: 7
Failures: 10
Total: 17

1959

Discoverer 8
Discoverer 7
Explorer 7
Vanguard 3
Discoverer 6
Discoverer 5
Explorer 6
Discoverer 2
Pioneer 4
Discoverer 1
Vanguard 2

Atlas-Able 4
Transit 1A
Beacon 2
Explorer S-1
Discoverer 4
Vanguard SLV 6
Discoverer 3
Vanguard SLV 5

*Successes: 11
Failures: 8
Total: 19

1960

Discoverer 19
Discoverer 18
Tiros 2
Discoverer 17
Explorer 8
Courier 1B
Discoverer 15
Discoverer 14
Echo 1
Discoverer 13
Transit 2A
Midas 2
Discoverer 11
Transit 1B
Tiros 1
Pioneer 5

Atlas-Able 5B
Explorer S-56
Transit 3A
Discoverer 16
Samos 1
Atlas-Able 5A
Courier 1A
Discoverer 12
Echo A 10
Explorer S-48
Midas 1
Discoverer 10
Discoverer 9

*Successes: 18
Failures: 13
Total: 28

1961

Atlas-Agena B
Discoverer 36
Mercury-Atlas 5
Ranger 2
Transit 4B
Discoverer 35
Discoverer 34
Midas 4
Discoverer 32
Discoverer 31
Mercury-Atlas 4
Discoverer 30
Discoverer 29
Explorer 13
Ranger 1
Explorer 12
Midas 3
Tiros 3
Discoverer 28
Transit 4A
Discoverer 25
Explorer 11
Discoverer 23
Explorer 10
Transit 3B
Discoverer 21
Discoverer 20
Explorer 9
Samos 2

Atlas-Agena B
Mercury-Scout 1
Discoverer 33
Samos 3
Discoverer 29
Discoverer 27
Explorer S-55
Discoverer 24
Explorer S-45A
Mercury-Atlas 3
Discoverer 22
Explorer S-45

*Successes: 29
Failures: 12
Total: 41

1962

Transit 5A
Explorer 16
Thor-Agena D
Relay 1
Thor-Agena D
Thor-Agena D
Thor-Agena B
Atlas-Agena B
Thor-Agena B
Anna 1B
Explorer 15
Starad
Ranger 5
Thor-Agena B
Mercury-Atlas 8
Explorer 14
Thor-Agena D
Alouette 1
Tiros 6
Thor-Agena B
Thor-Agena B
Thor-Agena D
Mariner 2
Scout
Atlas-Agena B
Thor-Agena D
Thor-Agena B
Thor-Agena B
Atlas-Agena B
Telstar 1
Thor-Agena D
Thor-Agena B
Tiros 5
Thor-Agena B
Atlas-Agena B
Thor-Agena B
Thor-Agena B
Mercury-Atlas 7
Thor-Agena B
Thor-Agena B
Atlas-Agena B
Ariel 1
Ranger 4
Thor-Agena B
Atlas-Agena B
Atlas-Agena B
OSO 1
Discoverer 38
Thor-Agena B
Mercury-Atlas 6
Tiros 4
Ranger 3

Atlas-Agena B
Mariner 1
Scout
Anna 1A
Solrad 4B
Composite 1
Discoverer 37

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*Successes: 52
Failures: 7
Total: 59

1963

TAT-Agena D
Tiros 6
Explorer 19
Atlas-Agena D
Thor-Able Star
Thor-Agena D
Atlas-Centaur 2
Explorer 16
TAT-Agena D
Atlas-Agena D
Vela 1 & 2
Thor-Able Star
TAT-Agena D
Atlas-Agena D
Thor-Agena D
TAT-Agena D
TAT-Agena D
Syncom 2
Atlas-Agena B
Thor-Agena D
Atlas-Agena D
TAT-Agena B
Geophysical Research Satellite
TAT-Agena D
Tiros 7
Scout
Thor-Agena D
TAT-Agena D
TAT-Agena D
Mercury-Atlas 9
Atlas-Agena B
Telstar 2
Explorer 17
Thor-Agena D
Scout
Syncom 1
Thor-Agena D
Thor-Agena D

Thor-Agena D
Scout
Atlas-Agena 3
Thor-Agena D
Scout
Scout
TAT-Agena D
TAT-Agena D

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*Successes: 38
Failures: 8
Total: 46

1964

TAT-Agena D
Explorer 26
TAT-Agena D
San Marco 1
Thor-Able Star
Atlas Centaur 4
Transtage
Atlas-Agena D
Mariner 4
Explorer 24 & 25
TAT-Agena D
Explorer 23
Mariner 3
TAT-Agena D
TAT-Agena D
Atlas-Agena D
TAT-Agena D
Explorer 22
Thor-Able Star
TAT-Agena D
Explorer 21
Atlas-Agena D
Saturn SA-7
TAT-Agena D
OGO 1
Nimbus 1
Explorer 20
TAT-Agena D
Syncom 3
Atlas-Agena D
TAT-Agena D
Ranger 7
Vela 3 & 4
TAT-Agena D
Atlas-Agena D
TAT-Agena D
TAT-Agena D
Thor-Agena C
TAT-Agena D
TAT-Agena D
Scout
Saturn SA-5
Atlas-Agena D
TAT-Agena D
Atlas-Agena D
Gemini-Titan 1
Ariel 2
Atlas-Agena D
TAT-Agena D
Atlas-Agena D
TAT-Agena D
Ranger 8
Saturn SA 5
Echo 2
Relay 2
Thor-Agena D
TAT-Agena D

Atlas-Agena D
Titan IIIA
Atlas Centaur
Environmental Sciences Research Satellite
Thor-Able Star
TAT-Agena C
Bosco-Explorer A

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*Successes: 57
Failures: 7
Total: 64

1965

TAT-Agena D
Scout
LES 3, 4 et. al.
Pioneer 6
Gemini 8
TAT-Agena D
FR 1
Gemini 7
Alouette 2 et. al.
Explorer 30
Atlas-Agena D
Explorer 29
TAT-Agena D
OV2 1, LCS 2
OGO 2
TAT-Agena D
OV1 2
Atlas-Agena D
TAT-Agena D
Thor-Altair
Gemini 5
TAT-Agena D
Surcal et. al.
Atlas-Centaur 6
Secor 5
Atlas-Agena D
Pegasus 3
Vela 5 & 6
TAT-Agena D
TAT-Agena D
Tiros 10
Atlas-Agena D
Thor-Able Star
Titan IIIC
TAT-Agena D
Gemini 4
Explorer 28
Atlas-Agena D
Pegasus 2
Thor-Altair
TAT-Agena D
LES 2, ECS 1
TAT-Agena D
Explorer 27
Atlas-Agena D
Early Bird Snapshot
TAT-Agena D
Gemini 3
Ranger 9
Thor-Altair
Atlas-Agena D
Thor-Able Star
GGS 2 & 3 et. al.
TAT-Agena D
Ranger 8
Pegasus 1
LES 1
OSO 2
Atlas-Agena D
Tiros 9
Thor-Altair
TAT-Agena D

Gemini 6 Target
Thor-Agena D
OSO C
Atlas-Agena D
OV1 3
Atlas Centaur
OV1 1

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*Successes: 83
Failures: 7
Total: 78

1966

TAT-Agena D
Biosatellite 1
Titan IIIB-Agena D
OV1 9 & 10
ATS 1
Atlas-Agena D
Gemini 12
Gemini 12 Target
TAT-Agena D
Lunar Orbiter 2
OV4 3 et. al.
Atlas-Agena D
OV3 2
Atlas Centaur 9
Intelsat IIA
Atlas-Agena D
EGRS-6
ESSA 3
Titan IIIB-Agena D
TAT-Agena D
Surveyor 2
Atlas-Agena D
Thor-Burner II
Gemini 11
Gemini 11 Target
ERS 15
Scout
Pioneer 7
Atlas-Agena D
Lunar Orbiter 1
Thorad-Agena D
OV3 3
Titan IIIB-Agena D
Gemini 10
Gemini 10 Target
OV1 8
Atlas-Agena D
Saturn I
Explorer 33
Pageos
TAT-Agena D
IDCSP 1-7, GGTS 1
OV3 4
Secor 6, ERS 16
OGO 3
Atlas-Agena D
Gemini 9
Gemini 9, Target B
Surveyor 1
Explorer 32
TAT-Agena D
Scout
Nimbus 2
Atlas-Agena D
OV3 1
Atlas-Agena D
GAO 1
Atlas Centaur
TAT-Agena B
Thor-Altair
OV1 4 & 5
Scout
Atlas-Agena D
Gemini 8
Gemini 8 Target
TAT-Agena D
ESSA -2
Atlas-Agena D
TAT-Agena D
ESSA 1
TAT-Agena D
Scout
Atlas-Agena B

IDCSP (8 satellites)
Gemini 9 Target A
TAT-Agena D
Thor-Altair

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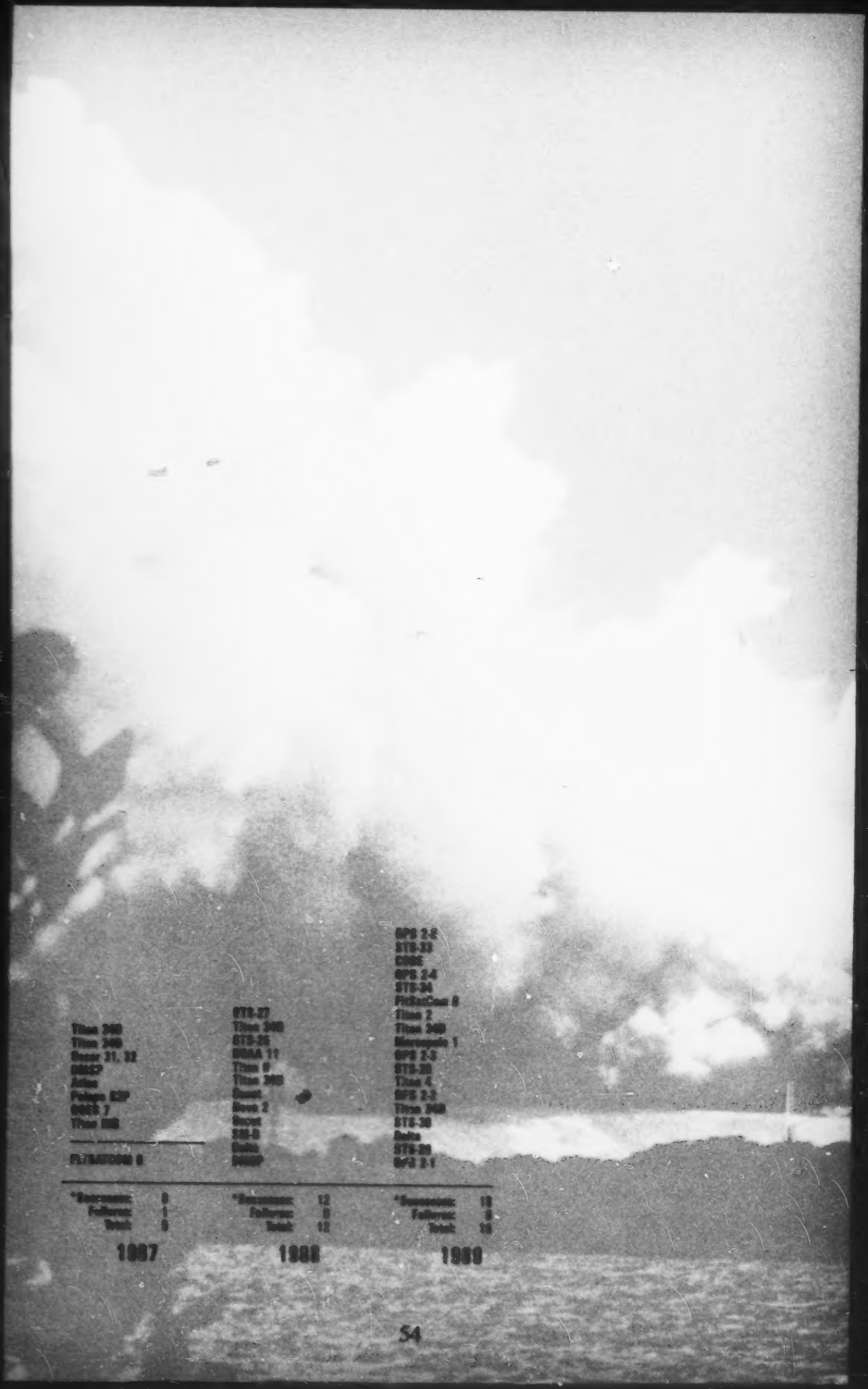
*Successes: 73
Failures: 4
Total: 77

Pioneer 8
LTTAT-Agena D
Titan IIIB-Agena D
OV3 6
ESSA 6
Apollo 4
Surveyor 5
ATS 3
LTTAT-Agena D
Titan IIIB-Agena D
OSO 4
Thor-Burner II
Intelsat IID
Scout
Titan IIIB-Agena D
LTTAT-Agena D
Surveyor 5
Biosatellite 2
Thor-Burner II
Titan IIIB-Agena D
LTTAT-Agena D
Lunar Orbiter 5
OGO 4
OV1 12 & 86
TAT-Agena D
Explorer 35
Surveyor 4
OSCAR 16-18 et. al.
Canar II, Aurora 1
Titan IIIB-Agena D
LTTAT-Agena D
Mariner 5
Atlas-Agena D
OGGE 4, 5 et. al.
Explorer 36
Atlas-Agena D
Scout
LTTAT-Agena D
Ariel 3
Lunar Orbiter 4
Vela 7, 8 et. al.
San Marco 2
ESSA II
Surveyor 3
Scout
ATS 2
TAT-Agena D
Intelsat IIC
OGO 3
Titan IIIC-Agena D
TAT-Agena D
Thor-Burner II
Lunar Orbiter 2
Atlas-Agena D
ESSA 4
OSCAR 9-10
TAT-Agena D
Intelsat IID
OSO 2A
Titan IIIB-Agena D
OV1 5
*Successes: 38
Failures: 4
Total: 42
1967
Apollo 9
Intelsat IIIB
ESSA 9
LTTAT-Agena D
OAO 2
NEBS 1
Titan IIIB-Agena D
Pioneer 9, TETR 2
Titan IIIB-Agena D
TAT-Agena D
Thor-Burner II
Apollo 7
LTTAT-Agena D
Aurora (ESRO 1A)
OV2 5 et. al.
TAT-Agena D
Titan IIIB-Agena D
ESSA 7
ATS 4
Explorer 39 & 40
LTTAT-Burner II
Titan IIIB-Agena D
Atlas-Agena
OV1 15 & 16
Explorer 38
LTTAT-Agena D
IMSCS 19-26
Titan IIIB-Agena D
Thor-Burner II
Iris (ESRO 2B)
LTTAT-Agena D
Titan IIIB-Agena D
OV1 13 & 14
Apollo 8
LTTAT-Agena D
Titan IIIC-Agena D
Explorer 37
OGO 5
Canal
LTTAT-Agena D
Apollo 5
Titan IIIB-Agena D
TAT-Agena D
Explorer 30
Surveyor 7
Intelsat IIIA
OV5 6 et. al.
Biosat 2, Cosar 10
*Successes: 46
Failures: 1
Total: 47
1968
Thorad-Agena D
Skynet 1
Apollo 12
Azur 1 (GRS A)
Titan IIIB-Agena D
Boreas (ESRO 1B)
LTTAT-Agena D
LTTAT-Agena D
Titan IIIB-Agena D
ATS 5
OGO 6, PAC 1
LTTAT-Agena D
Intelsat IIIC
LTTAT-Agena D
Thor-Burner II
Apollo 11
Biosatellite 3
Explorer 41
OGO 6
Titan IIIB-Agena D
Vela 9, 10 et. al.
Intelsat IIID
Apollo 10
LTTAT-Agena D
Titan IIIB-Agena D
Biosat 3, Cosar 13
Atlas-Agena D
Mariner 7
LTTAT-Agena D
OV1 17,18 19 & 17A
Titan IIIB-Agena D
Apollo 9
ESSA 8
Mariner 6
Tacsat 1
Intelsat IIIC
LTTAT-Agena D
NNS 1
Titan IIIB-Agena D
OGO 5
Pioneer E, TETR2
*Successes: 40
Failures: 1
Total: 41
1969
Explorer 42
NOAA-1
Thorad-Agena D
OFO 1, RM
Titan IIIC
Titan IIIB-Agena D
Thor-Burner II
Thor-Agena D
Scout
Thorad-Agena D
Skynet II
Titan IIIB-Agena D
Intelsat III F-8
Titan IIIB-Agena D
Titan IIIB-Agena D
Atlas-Agena D
Thor-Agena D
Intelsat III F-7
Titan IIIB-Agena D
Apollo 13
Vela 11, 12
Biosat 4, TOPO 1
NATO 1
Thorad-Agena D
Thor-Burner II
SERT 2
ITOS 1, Oscar 5
Intelsat IV F-6
Titan IIIB-Agena D
OAO 8
*Successes: 29
Failures: 1
Total: 30
1970
Intelsat IV F-3
Thorad-Agena D
Ariel 4
Explorer 45
DSCS 1, 2
Titan IIIB-Agena D
NOAA 2
Space Test Program
Thor-Burner II
OSO 7, TETR 4
LTTAT-Agena D
EOLE 1
Titan 111B-Agena D
OV1-20 et. al.
Apollo 15, P&F
Thorad-Agena D
Explorer 44
Titan IIIB
LTTAT-Agena D
Mariner 9
Titan IIIC
San Marco 3
Titan IIIB-Agena D
IBSS 2
LTTAT-Agena D
Titan IIIB-Agena D
Explorer 43
Thor-Burner II
NATO 2
Apollo 14
Intelsat IV F-2
Titan IIIB-Agena D
Atlas Agena D
PAET Probe
Mariner H
Thorad-Agena D
*Successes: 32
Failures: 4
Total: 36
1971

1972	1973	1974	1975	1976
Titan 3B-Agena	Explorer 51	Symphonie	Titan IIIC	Titan IIID
Atlas-Agena	DSCS II-B3, B4	Helios	RCA Satcom 1	Marisat 3
Aeros	Skylab 4	Skynet 2B	Titan IIID	Titan IIIB-Agena
Nimbus 5	Titan IIID	Intelsat IV F-8	Explorer 55	AMS 1
Apollo 17	NOAA 3	NOAA	GOES 1	TIP 3
ESRO IV	Mariner 10	Titan IIID	TIP 2	Satellite Data Sys. 2
Explorer 48	Transit	Ariel 5	Titan IIIB	NOAA 5
AMIK 1	Explorer 50	Westar B	Explorer 54	Comstar 2
Thor-Burner II	Titan IIIB-Agena B	ARS	Intelsat IVA F-1	Palapa 1
NOAA 2, OSCAR 6	Intelsat IV F-7	Titan IIIB-Agena	Viking 2	Titan IIID
Titan IIID	Titan IIIB-Agena D	Thor-Burner IIA	Symphonie B	Titan IIIC
Atlas F-Burner II	Thor-Burner II	Aeros 2	Viking 1	Marisat 2
Explorer 47	Skylab 3	Timation 3	COS B	Titan IIIB
Triad 01-1	Titan IIID	Titan IIIB-Agena	Apollo 18	P76-5
Titan IIIB-Agena	Titan IIIC	Hawkeye	OSO 8	Comstar 1
GAO 3	Explorer 49	ATS 6	Atlas-Agena	Lageos 1
Explorer 46	Skylab 2	SMS 1	Nimbus 6	Atlas
ERTS 1	Titan IIIB-Agena D	Westar A	XSU 1	Xato IIIA
Titan IIID	Skylab 1	Titan IIID	SMSP	RCA Satcom 2
Intelsat IV F-5	Anik 2	Thor-Burner IIA	Intelsat IV F-1	Titan IIIB-Agena D
Thorad-Agena	Pioneer 11	UK X4 (Miranda)	DSCS II-B5, B6	Titan IIIC
Thorad-Agena	Titan IIID	San Marco 4 (C2)	AMIK 3	Marisat 1
Apollo 16, P&F	Atlas-Agena D	Titan IIIB-Agena	Explorer 53	Thor-Burner 2
Thor-Burner II		Skynet 2A	Titan IIIB	Intelsat IVA F-2
Titan IIIB/Agena			GEOS 3	CTS
TD 1A			Titan IIIB	Helios 2
Pioneer 10			SMS 2	
Titan IIIC			Landsat 2	
HEOS A2				
Intelsat F IV				
Titan IIID				
Titan IIIB-Agena	ITOS-E	Viking Proof Test	Explorer	
Titan IIIB-Agena	Titan IIIB-Agena B		Atlas F	
			Intelsat IV F-6	
*Successes: 31	*Successes: 23	*Successes: 24	*Successes: 28	*Successes: 28
Failures: 2	Failures: 2	Failures: 1	Failures: 3	Failures: 0
Total: 33	Total: 25	Total: 25	Total: 31	Total: 28

Sakura
Atlas-Agena D
NOSS-2
Marecsat 1
Telesat
ISEE 1 & 2
Titan IIIB
Voyager 1
Sirio
Voyager 2
MEAO-1
Marecsat (GOMS-1)
Titan IIID
ATS-8
GOES-2
SMSP
Intelsat IVA F-4
Atlas-Agena
DSCS II
SESS
Titan IIID
Pelapa 2
Titan IIIC
Nato IIID
Intelsat IVA
DTS
*Successes: 24
Failures: 2
Total: 26
1977
Anik 4
DSCS II F
GPS-4
NATO IIIC
MEAO 2
Minitrack 7/Camsat
Titan II
GPS 3
ISEE 3
Pioneer Venus/Multiprobe
Titan IIIB-Agena D
GEOS 2
Comstar 3
Sacsat 1
GOES 3
Titan IIIB
Titan IIIC
Pioneer Venus/Orbiter
MSS 2
DTS-2
SMSP
ACSNM
VHBI
DMSP/S II
Intelsat IVA F-5
Titan IIID
Landsat 3/Seasat A
Titan IIIB-Agena A
RBS-1
FLTSATCOM 1
IUE
Intelsat IVA F-1
DSCS II
*Successes: 30
Failures: 1
Total: 31
1978
Satcom 3
DSCS II
Magsat
Titan III C
MEAO 3
Westar 3
NOAA 6
Titan IIIC
SMSP
HK 8
Titan IIIB
FLTSATCOM 2
Titan IIID
P78-1
SAGE
SCATHA
*Successes: 16
Failures: 0
Total: 16
1979
Titan IIIB-Agena
Intelsat V F-2
SBS-1
FLATSATCOM 4
GOES 4
Titan IIID
NOAA D(7)
GPS-6
Atlas F
Solar Max
GPS-5
Titan IIID
FLTSATCOM 3
*Successes: 13
Failures: 0
Total: 13
1980
Intelsat V F-3
RCA-Satcom IIIR
Columbia (STS-2)
Titan IIIC
SME and UOSAT
SBS 2
Titan IIID
FLTSATCOM 5
Dynamic Explorer 1 & 2
NOAA 7
Intelsat V F-1
GOES 5
Nova 1
Titan IIIB-Agena D
Columbia (STS-1)
Titan IIIC
Titan IIIB-Agena D
Comstar D-4
NAVSTAR GPS
*Successes: 18
Failures: 1
Total: 19
1981

1982	1983	1984	1985	1986
Atlas E	STS-9	Titan 34D	Scout	
Titan IIID	Atlas F	NOAA-9	STS 61-B	
STS-5	Galaxy 2	Titan 34D	STS 61-A	
DSCS II-F10,	RCA Satcom VII	Nato 3B	Navstar 11	
DSCS III-A1	STS-8	STS 51-A	STS 51-J	
RCA Satcom V	Titan IIID-Agena D	Nova 3	Intelsat VA F-12	
Intelsat V F-5	Telstar 301 (J-1)	STS 41-B	STS 51-I	
Anik D-1	Atlas F	Galaxy 3	Scout	
Landsat 4	Galaxy 1	Navstar 10	STS 61-F	
STS 4	Scout	STS 41-D	Intelsat VA F-11	FLTSATCOM 7
Westar V	Titan 34D	Titan IIIB	STS 51-G	Polar BEAR
Titan IIID	STS-7	Anik C 1,2,3	STS 51-B	NOAA-10
Insat 1A	Atlas	Titan 34D	STS 51-D	Delta
STS-3	Exosat	Navstar 9	Intelsat VA F-10	Atlas F
Titan IIIC	Intelsat V F-8	Intelsat VA F-9	Exosat	STS 61-C
Intelsat V F-4	GOES 6	Titan IIIB	Titan IIIB	
Westar IV	Titan IIIB	Titan 34D	STS 51-C	
Titan III	RCA Satcom VI	STS 41-C		
RCA Satcom IV	STS-6	Landsat 5		GOES 7
	NOAA 8	Atlas F		Titan 34D
	Atlas	STS 41-B	Titan 34D	STS 51-I
	IRAS	Titan 34D		
*Successes: 10	*Successes: 22	*Successes: 22	*Successes: 17	*Successes: 6
Failures: 0	Failures: 0	Failures: 0	Failures: 1	Failures: 3
Total: 10	Total: 22	Total: 22	Total: 18	Total: 9


1987
1988
1989

STS Payload Deployment Record

[1]IUS failure cast TDRS into incorrect orbit; satellite subsequently boosted to geosynchronous orbit using its own thrusters

[2]Perigee Kick Motor failure. Satellites returned to earth via STS 51-A

*Desired orbit not achieved

1982

Anik C3 by PAM-D (STS-5)
SBS 3 by PAM-D (STS-5)

Successes:	2
*Failures:	0
Total:	2

1983

Insat 1B by PAM-D (STS-8)
SPAS by RMS (STS-7)
Palapa B1 by PAM-D (STS-7)
Anik C2 by PAM-D (STS-7)

TDRS 1 by IUS (STS-6)[1]

Successes:	4
*Failures:	1
Total:	5

1984

Leasat 2 by PKM (STS 51-A)
Anik D2 by PAM-D (STS 51-A)
ERBS by RMS (STS 41-G)
Telstar 3C by PAM-D (STS 41-D)
Leasat 1 by PKM (STS 41-D)
SBS 4 by PAM-D (STS 41-D)
LDEF by RMS (STS 41-C)
WT (STS 41-B)

Palapa B2 by PAM-D (STS 41-B)[2]
Westar VI by PAM-D (STS 41-B)[2]

Successes:	8
*Failures:	2
Total:	10

[3]Faulty switch prevented Perigee Kick Motor firing; satellite repaired on orbit (STS 51-I), successfully boosted into geosynch

1985	1986	1988
OEX by EVA (STS 61-B)		
Satcom K-2 by PAM-D (STS 61-B)		
Aussat 2 by PAM-D (STS 61-B)		
Morelos 2 by PAM-D (STS 61-B)		
Glomr (STS 61-A)		
Unannounced by IUS (STS 51-J)		
Unannounced by IUS (STS 51-J)		
Leasat 4 by PKM (STS 51-I)		
ASC 1 by PAM-D (STS 51-I)		
Aussat 1 by PAM-D (STS 51-I)		
PDP by RMS (STS 51-F)		
Spartan 1 by RMS (STS 51-G)		
Telstar 3D by PAM-D (STS 51-G)		
Arabsat 1B by PAM-D (STS 51-G)		
Morelos 1 by PAM-D (STS 51-G)		
Nusat (STS 51-B)		
Anik C1 by PAM-D (STS 51-D)		
Unannounced by IUS (STS 51-C)		
Leasat 3 by PKM[3] (STS 51-D)	Satcom K-1 by PAM-D2 (STS 61-C)	Unannounced (STS-27)
		TDRS 3 by IUS (STS-26)
Successes: 18	Successes: 1	Successes: 2
*Failures: 1	*Failures: 0	*Failures: 0
Total: 19	Total: 1	Total: 2

Unannounced (STS-33)
Galileo by IUS (STS-34)
Unannounced
Unannounced (STS-28)
Magellan by IUS (STS-30)
TDRS 4 by IUS (STS-29)

Successes:	6
*Failures:	0
Total:	6

1989

*Desired orbit not achieved

Payloads in Orbit

Olympus 1, courtesy of British Aerospace

Australia	4	Japan	37
Brazil	2	Luxembourg	1
Canada	14	Mexico	2
ESA	19	NATO	6
France	16	PRC	7
France/FRG	2	Saudi Arabia	2
FRG	8	Spain	1
India	8	Sweden	2
Indonesia	4	UK	10
ITSO	37	US	557
Italy	1	USSR	1,124
Subtotal	115	Subtotal	1,749
Total			**1,864**

As of December 31, 1989

Worldwide Successful Space Launches

Year	USSR	US†	France	Australia	China	Japan	UK	Europe**	India	Israel	Total
1957	2										2
1958	1	7									8
1959	3	11									14
1960	3	16									19
1961	6	29									35
1962	20	52									72
1963	17	38									55
1964	30	57									87
1965	48	63	1								112
1966	44	73	1								118
1967	66	58*	2	1							127
1968	74	45									119
1969	70	40									110
1970	81	29*	2		1	1					114
1971	83	32*	1		1	2	1				120
1972	74	31*				1					106
1973	86	23									109
1974	81	24*				1					106
1975	89	28*	3		3	2					125
1976	99	26			2	1					128
1977	98	24				2					124
1978	88	32			1	3					124
1979	87	16				2		1			106
1980	89	13				2			1		105
1981	98	18			1	3		2	1		123
1982	101	18			1	1					121
1983	98	22‡			1	3		2‡	1		127
1984	74	18				2		7			101
1985	98	17			1	2		3			121
1986	91	6			2	2		2			103
1987	95	8			2	3		2			110
1988	90	12*			4	2		7		1	116
1989	74	18				2		7			101
Total	**2,181**	**908**	**10**	**1**	**23**	**38**	**1**	**30**	**3**	**1**	**3,196**

* Italy has launched nine spacecraft from its San Marco platform. U.S. Scout rockets were used for these launches, so NASA includes them in the U.S. launch total.

** Launches through March 1984 were ESA sponsored. Arianespace, a private company jointly held by European companies, has had launch responsibility since May of that year.

† Does not include payloads launched from space shuttle

‡ ESA launch from WSMC used U.S. Delta 3914 and is included in U.S. total

Satellites Decayed in 1989

Int'l Desig.	Satellite	Decay Date	Launch Date
1965 007A	OSO 2	8/9	2/3/65
1965 021A	None	12/31	3/18/65
1966 057A	Kosmos 122	11/14	6/25/66
1967 039A	Kosmos 156	10/23	4/27/67
1967 102A	Kosmos 184	4/2	10/24/87
1968 019A	Kosmos 206	4/22	3/14/68
1971 012C	Calsphere 3	10/17	2/17/71
1971 012D	Calsphere 4	9/20	2/17/71
1976 085A	Kosmos 851	8/4	8/27/76
1978 009A	Molniya 3-9	12/5	1/24/78
1978 119A	Kosmos 1064	11/12	12/20/78
1979 013A	Sage	4/11	2/18/79
1979 031A	Molniya 1-43	12/9	4/12/79
1979 051A	Bhaskara	2/17	6/7/79
1979 104A	CAT	11/27	12/24/79
1980 014A	Solar Max	12/2	2/14/80
1980 037A	Kosmos 1179	7/18	5/14/80
1981 095A	Kosmos 1310	4/3	9/23/81
1981 100B	Uosat	10/13	10/6/81
1982 026A	Cosmos 1345	9/27	3/31/82
1982 121A	Kosmos 1427	10/5	12/29/82
1983 034A	Kosmos 1453	5/8	4/19/83
1983 101A	Kosmos 1501	5/26	9/30/83
1984 015A	Ohzora	7/19	2/14/84
1984 104A	Kosmos 1601	11/29	9/27/84
1985 050A	Kosmos 1662	11/16	6/19/85
1985 114A	None	5/11	12/13/85
1986 067A	Kosmos 1776	12/15	9/3/86
1987 004A	Kosmos 1813	3/13	1/15/87
1987 061A	Kosmos 1868	3/3	7/14/87
1987 064A	Kosmos 1870	7/29	7/25/87
1988 060A	Kosmos 1958	3/21	7/14/88
1988 087A	Offeq 1	1/14	9/19/88
1988 101A	Kosmos 1979	12/25	11/18/88
1988 104A	Soyuz TM-7	4/27	11/26/88
1988 110A	Kosmos 1984	2/13	12/16/88
1988 114A	Progress 39	2/7	12/25/88
1988 116A	Kosmos 1986	2/11	12/29/88
1989 002A	Kosmos 1990	2/11	1/12/89
1989 003A	Kosmos 1991	2/1	1/18/89
1989 007A	Kosmos 1993	3/27	1/28/89
1989 008A	Progress 40	3/5	2/10/89
1989 010A	Kosmos 2000	3/2	2/10/89
1989 012A	Kosmos 2002	10/15	2/14/89

Int'l Desig.	Satellite	Decay Date	Launch Date
1989 015A	Kosmos 2003	3/3	2/17/89
1989 019A	Kosmos 2005	4/25	3/2/89
1989 021A	STS-29	3/18	3/13/89
1989 022A	Kosmos 2006	3/30	3/16/89
1989 023A	Progress 41	4/25	3/16/89
1989 024A	Kosmos 2007	9/22	3/23/89
1989 029A	Kosmos 2017	4/19	4/6/89
1989 031A	Kosmos 2018	6/19	4/20/89
1989 032A	Foton 2	5/11	4/26/89
1989 033A	STS-30	5/8/89	5/4/89
1989 034A	Kosmos 2019	5/18	5/5/89
1989 036A	Kosmos 2020	7/15	5/17/89
1989 037A	Kosmos 2021	7/6	5/24/89
1989 038A	Resurs-F1	6/17	5/25/89
1989 038C	Pion 1	7/23	5/25/89
1989 038D	Pion 2	7/24	5/25/89
1989 040A	Kosmos 2025	6/15	6/1/89
1989 047A	Cosmos 2028	7/6	6/16/89
1989 049B	Resurs-F2	7/11	6/27/89
1989 051A	Kosmos 2029	7/19	7/5/89
1989 054A	Kosmos 2030	7/29	7/12/89
1989 055A	Resurs-F3	8/8	7/18/89
1989 055C	Pion 3	9/19	7/18/89
1989 055D	Pion 4	9/19	7/18/89
1989 056A	Kosmos 2031	9/15	7/18/89
1989 057A	Kosmos 2032	8/3	7/20/89
1989 060A	Kosmos 2035	8/16	8/2/89
1989 061A	STS-28	8/13	8/8/89
1989 063A	Resurs-F4	9/14	8/15/89
1989 065A	Kosmos 2036	9/5	8/22/89
1989 066A	Progress M	12/1	8/23/89
1989 073A	Resurs-F5	9/22	9/6/89
1989 075A	Kosmos 2044	9/29	9/15/89
1989 076A	Kosmos 2045	10/2	9/22/89
1989 082A	Kosmos 2047	11/21	10/3/89
1989 083A	Kosmos 2048	10/26	10/17/89
1989 084A	STS-34	10/23	10/18/89
1989 090A	STS-33	11/28	11/23/89

The Solar Maximum Mission, the first satellite repaired on orbit, plunged into the atmosphere at 10:56 December 2. The nine-year-old, 2,315-kg satellite broke up over the Indian Ocean, with any surviving fragments splashing down around 3.1 deg. n lat., 88.6 deg. e long. Solar Max was launched February 14, 1980, at the peak of the 11-year solar cycle. Ten months later, its attitude control system failed. In April 1984, STS-41C astronauts captured the tumbling satellite and returned it to the shuttle cargo bay for repair. The revitalized Solar Max resumed its mission, returning good solar constant, solar flare and corona data until shortly before its uncontrolled reentry.

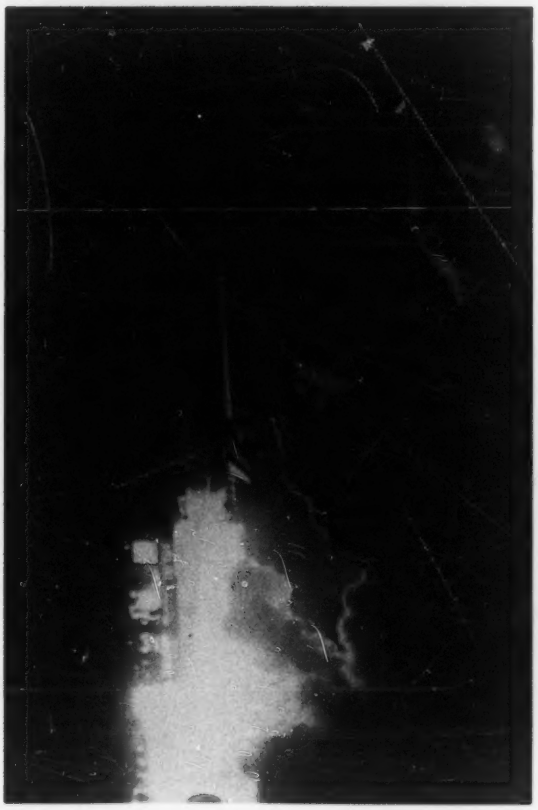
Manned Space Flight Records

	Total Flights	Earth Missions	Lunar Missions	Total Crew-hours
United States	62	53	9	46,351
USSR	66	66	–	158,727
Total	**128**	**119**	**9**	**205,078**

First manned flight: Vostok 1
First EVA: Voskhod 2
Longest mission: Soyuz TM-4/TM-6 (365 days, 22 hrs, 39 mns)
First rendezvous mission: Gemini 7 and 6
First docking flight: Gemini 8
First lunar orbit: Apollo 8
First crew exchange: Soyuz 4,5
First manned lunar landing: Apollo 11
First triple launch/manned: Soyuz 6,7,8

Heaviest manned spacecraft:
On-orbit – STS-34 (119,943 kg)
At liftoff – STS-29 (2,049,888 kg)
First use of reusable manned spacecraft: STS 1
First modular space station assembly: Salyut 7/Kosmos 1443
First retrieval, repair of satellite: STS 41-C
First space construction: STS 61-B
First station-to-station crew transfer: Mir/Soyuz T-15 to Salyut 7

Summary Log of Space Launches



The Summary Log lists all known 1989 orbital launches through December 31. Data was compiled from the Goddard Space Flight Center *Satellite Situation Report*; Teledyne Brown Engineering's *The Soviet Year in Space 1989*; The Royal Aerospace Establishment *Table of Artificial Satellites*; United Nations registration documents; The British Interplanetary Society's *Spaceflight*; and public announcements from agencies responsible for project direction. While every effort is made to verify the accuracy of the data, some information varies from source to source and discrepancies may occur.

Launch Date: Universal time

Launch Site:
- ESMC = Eastern Space and Missile Center, Cape Canaveral, FL
- KSC = Kennedy Space Center, FL
- WSMC = Western Space and Missile Center, Vandenberg AFB, CA
- STS = Space Transportation System

Weight: Launch weight in kilograms unless otherwise indicated; Soviet, Chinese weights are approximate

Orbital Data: Initial data for satellites launched and reentered; current for satellites still in orbit (December 31, 1989)

Period: Minutes

Perigee and Apogee: Kilometers

Inclination: Degrees to the equator

Summary Log of Space Launches 1989

Name	Int'l Desig.	Proj. Dir.	Launch Data			Weight (kg)	Orbital Data				Status
			Date	Site	Vehicle		Period	Perigee	Apogee	Incl.	
Kosmos 1987	1989 001A	USSR	Jan 10	Tyuratam	D-1-e	1,400	675.7	19,117	19,142	64.9	Glonass navigation system
Kosmos 1988	1989 001B	USSR	Jan 10	Tyuratam	D-1-e	1,400	675.7	19,119	19,141	64.9	Glonass navigation system
Kosmos 1989	1989 001C	USSR	Jan 10	Tyuratam	D-1-e	1,415	675.5	19,102	19,149	64.9	Geodetic. 1st in Etalon series
Kosmos 1990	1989 002A	USSR	Jan 12	Plesetsk	A-2	6,300	89.8	259	268	82.6	Photo recon. Reentered 2/11
Kosmos 1991	1989 003A	USSR	Jan 18	Tyuratam	A-2	6,300	92.2	347	414	70.0	Photo recon. Reentered 2/1
Gorizont 17	1989 004A	USSR	Jan 26	Tyuratam	D-1-e	2,120	1,436.2	35,776	35,804	1.5	Communications. Located above 53 deg. e
Kosmos 1992	1989 005A	USSR	Jan 26	Plesetsk	C-1	900	100.7	772	807	74.1	Store/dump communications
Intelsat VA F15	1989 006A	Intel.	Jan 27	Kourou	Ariane 2	1,977	1,436.1	35,775	35,799	0.0	International communications. Last in VA series. Stationed above 60 deg. e long.
Kosmos 1993	1989 007A	USSR	Jan 28	Tyuratam	A-2	6,500	89.6	173	361	64.7	Photo recon. Reentered 3/27
Progress 40	1989 008A	USSR	Feb 10	Tyuratam	A-2	7,250	91.6	347	363	51.6	Resupplied Mir. Docked 2/12; undocked 3/3; reentered 3/5
Kosmos 1994	1989 009A	USSR	Feb 10	Plesetsk	F-2	100	113.9	1,393	1,414	82.6	Communications
Kosmos 1995	1989 009B	USSR	Feb 10	Plesetsk	F-2	100	114.1	1,410	1,415	82.6	Communications
Kosmos 1996	1989 009C	USSR	Feb 10	Plesetsk	F-2	100	114.0	1,404	1,414	82.6	Communications
Kosmos 1997	1989 009D	USSR	Feb 10	Plesetsk	F-2	100	113.9	1,398	1,414	82.6	Communications
Kosmos 1998	1989 009E	USSR	Feb 10	Plesetsk	F-2	100	113.8	1,388	1,414	82.6	Communications
Kosmos 1999	1989 009F	USSR	Feb 10	Plesetsk	F-2	100	113.7	1,382	1,414	82.6	Communications
Kosmos 2000	1989 010A	USSR	Feb 10	Plesetsk	A-2	6,300	91.9	339	391	82.4	Photo recon. Reentered 3/2
Kosmos 2001	1989 011A	USSR	Feb 14	Plesetsk	A-2-e	1,900	717.7	623	39,728	62.8	Early warning
Kosmos 2002	1989 012A	USSR	Feb 14	Plesetsk	C-1	500	110.3	185	2,307	65.8	Minor military. Reentered 10/15
GPS 2-1	1989 013A	US	Feb 14	ESMC	Delta	1,665	718.0	20,018	20,346	55.1	2nd generation Navstar Global Positioning System satellite
Molniya 1-75	1989 014A	USSR	Feb 15	Tyuratam	A-2-e	1,800	717.8	458	39,901	62.9	Domestic communications
Kosmos 2003	1989 015A	USSR	Feb 17	Plesetsk	A-2	6,300	89.5	233	267	62.8	Photo recon. Reentered 3/3
Exos-D	1989 016A	Japan	Feb 21	Kagoshima	M-3S-2	295	205.1	262	10,021	75.1	Scientific. Studying Aurora Borealis, Auroral Australis
Kosmos 2004	1989 017A	USSR	Feb 22	Plesetsk	C-1	825	105.0	974	1,018	82.9	Navigation

Summary Log of Space Launches 1989

Name	Int'l Desig.	Proj. Dir.	Launch Data			Weight (kg)	Orbital Data				Status
			Date	Site	Vehicle		Period	Perigee	Apogee	Incl.	
Meteor 2-18	1989 018A	USSR	Feb 28	Plesetsk	F-2	1,500	104.1	941	960	82.5	Meteorological
Kosmos 2005	1989 019A	USSR	Mar 2	Plesetsk	A-2	6,500	89.6	189	326	62.8	Photo recon. Reentered 4/25
JCSAT 1	1989 020A	Japan	Mar 6	Kourou	Ariane 44LP	2,280	1,436.1	35,773	35,800	0.6	Japanese domestic communcations. Operational above 150 deg. e long.
MOP-1	1989 020B	ESA	Mar 6	Kourou	Ariane 44LP	681	1,436.2	35,779	35,798	0.7	Meteosat Operational Program. Weather imaging, environmental, atmospheric data. Geostationary at 0 deg.
STS-29	1989 021A	US	Mar 13	KSC	Discovery	119,269*	91.0	305	337	28.5	Crew: Michael Coats, commander; John Blaha, pilot; James Buchli, Robert Springer, James Bagian, mission specialists. Deployed TDRS 4. Landed 3/18 after 4 days, 23 hrs, 39 mns.
TDRS 4	1989 021B	US	Mar 13	STS-29	IUS	2,120	1,436.1	35,768	35,808	0.0	Satellite to satellite communications link. Located above 41 deg. w long.
Kosmos 2006	1989 022A	USSR	Mar 16	Plesetsk	A-2	6,300	91.9	320	380	62.8	Photo recon. Reentered 3/30
Progress 41	1989 023A	USSR	Mar 16	Tyuratam	A-2	7,250	91.0	348	363	51.6	Resupplied Mir. Docked 3/18; undocked 4/21. Reentered 4/25
Kosmos 2007	1989 024A	USSR	Mar 23	Tyuratam	A-2	7,000	89.4	229	283	64.7	Photo recon. Reentered 9/22
Kosmos 2008	1989 025A	USSR	Mar 24	Plesetsk	C-1	40	114.5	1,394	1,471	74.0	Tactical military comm.
Kosmos 2009	1989 025B	USSR	Mar 24	Plesetsk	C-1	40	114.7	1,409	1,473	74.0	Tactical military comm.
Kosmos 2010	1989 025C	USSR	Mar 24	Plesetsk	C-1	40	114.8	1,425	1,472	74.0	Tactical military comm.
Kosmos 2011	1989 025D	USSR	Mar 24	Plesetsk	C-1	40	115.0	1,440	1,472	74.0	Tactical military comm.
Kosmos 2012	1989 025E	USSR	Mar 24	Plesetsk	C-1	40	115.2	1,457	1,472	74.0	Tactical military comm.
Kosmos 2013	1989 025F	USSR	Mar 24	Plesetsk	C-1	40	115.4	1,465	1,481	74.0	Tactical military comm.
Kosmos 2014	1989 025G	USSR	Mar 24	Plesetsk	C-1	40	115.6	1,470	1,491	74.0	Tactical military comm.
Kosmos 2015	1989 025H	USSR	Mar 24	Plesetsk	C-1	40	114.7	1,470	1,511	74.0	Tactical military comm.
None	1989 026A	US	Mar 24	ESMC	Delta		94.5	487	499	47.7	
Tele-X	1989 027A	Sweden	Apr 2	Kourou	Ariane 2	2,142	1,436.1	35,664	35,908	0.0	TV, business communications to Nordic countries. Located above 5 deg. e long.
Kosmos 2016	1989 028A	USSR	Apr 4	Plesetsk	C-1	825	104.8	957	1,014	82.9	Navigation

*Orbiter/cargo weight. Total launch weight including fuel, boosters, 2,049,888 kg.

Summary Log of Space Launches 1989

Name	Int'l Desig.	Proj. Dir.	Launch Data			Weight (kg)	Orbital Data				Status
			Date	Site	Vehicle		Period	Perigee	Apogee	Incl.	
Kosmos 2017	1989 029A	USSR	Apr 6	Plesetsk	A-2	6,300	89.6	246	269	62.8	Photo recon. Reentered 4/19
Raduga 23	1989 030A	USSR	Apr 14	Tyuratam	D-1-e	1,965	1,435.1	35,767	35,796	1.4	Domestic communications. Stationed over 336 deg. e
Kosmos 2018	1989 031A	USSR	Apr 20	Plesetsk	A-2	6,500	89.9	181	352	62.8	Photo recon. Reentered 6/19
Foton 2	1989 032A	USSR	Apr 26	Plesetsk	A-2	6,200	90.5	216	380	62.8	Materials processing. Carried French microgravity exp. Reentered 5/11
STS-30	1989 033A	US	May 4	KSC	Discovery	98,533*	90.8	297	331	28.9	Crew: David Walker, commander; Ronald Grabe, pilot; Mark Lee, Norman Thagard, Mary Cleave, mission specialists. Deployed Magellan. Returned 5/8 after 4 days, 56 mns.
Magellan	1989 033B	US	May 5	STS	IUS	3,444	Trans-Venus trajectory				
Kosmos 2019	1989 034A	USSR	May 5	Plesetsk	A-2	6,300	89.9	187	355	62.8	Photo recon. Reentered 5/18
None	1989 035A	US	May 10	ESMC	Titan 34D		Elements not available				
Kosmos 2020	1989 036A	USSR	May 17	Tyuratam	A-2	6,500	89.6	172	337	64.8	Photo recon. Reentered 7/15
Kosmos 2021	1989 037A	USSR	May 24	Tyuratam	A-2	6,500	89.4	213	277	69.9	Topographic mapping. Reentered 7/6
Resurs-F 1	1989 038A	USSR	May 25	Plesetsk	A-2	6,300	89.7	254	273	82.3	Remote sensing. Deployed 2 subsatellites. Reentered 6/17
Pion 1	1989 038C	USSR	Jun 9	Resurs-F	A-2	78	89.7	257	270	82.3	Passive atmospheric research subsatellite. Reentered 7/23
Pion 2	1989 038D	USSR	Jun 9	Resurs-F	A-2	78	89.7	257	268	82.3	Passive atmospheric research subsatellite. Reentered 7/24
Kosmos 2022	1989 039A	USSR	May 31	Tyuratam	D-1-e	1,400	675.7	19,124	19,137	64.8	Glonass navigation system
Kosmos 2023	1989 039B	USSR	May 31	Tyuratam	D-1-e	1,400	675.7	19,095	19,165	64.8	Glonass navigation system
Kosmos 2024	1989 039C	USSR	May 31	Tyuratam	D-1-e	1,415	675.4	19,106	19,139	64.8	Geodetic. 2nd in series (Etalon)
Kosmos 2025	1989 040A	USSR	Jun 1	Plesetsk	A-2	6,300	89.5	179	356	62.8	Photo recon. Reentered 6/15
Superbird A	1989 041A	Japan	Jun 5	Kourou	Ariane 44L	2,489	1,436.2	35,776	35,799	0.0	Japanese domestic business communications. Located above 158 deg. e
DFS-1	1989 041B	FRG	Jun 5	Kourou	Ariane 44L	1,416	1,436.1	35,775	35,800	0.0	Multi-purpose telecommunications. Located above 23.5 deg. e long.
Kosmos 2026	1989 042A	USSR	Jun 7	Plesetsk	C-1	825	104.7	950	1,007	82.9	Navigation
Molniya 3-35	1989 043A	USSR	Jun 8	Plesetsk	A-2-e	1,800	717.8	594	39,763	62.8	Domestic communications

* Total liftoff weight was 2,049,877 kg

Summary Log of Space Launches 1989

Name	Int'l Desig.	Proj. Dir.	Launch Data			Weight (kg)	Orbital Data				Status
			Date	Site	Vehicle		Period	Perigee	Apogee	Incl.	
GPS 2-2	1989 044A	US	Jun 10	ESMC	Delta	1,665	718.0	19,962	20,401	54.7	2nd generation Navstar Global Positioning System satellite
Kosmos 2027	1989 045A	USSR	Jun 14	Plesetsk	C-1	900	94.6	483	519	65.8	Minor military
None	1989 046A	US	Jun 14	ESMC	Titan 4	Elements not available					First Titan 4 launch
Kosmos 2028	1989 047A	USSR	Jun 16	Tyuratam	A-2	6,300	89.6	229	287	69.9	Photo recon. Reentered 7/6
Raduga 24	1989 048A	USSR	Jun 21	Tyuratam	D-1-e	1,965	1,436.2	35,765	35,814	1.4	Domestic communications. Possibly a new series. Positioned above 49 deg. e
Resurs-F 2	1989 049A	USSR	Jun 27	Plesetsk	A-2	6,300	89.6	260	274	82.5	Remote sensing. Reentered 7/11
Nadezhda 1	1989 050A	USSR	Jul 4	Plesetsk	C-1	825	104.8	957	1,011	83.0	Navigation; carries COSPAS/SARSAT transponder
Kosmos 2029	1989 051A	USSR	Jul 5	Plesetsk	A-2	6,300	91.5	334	358	82.4	Photo recon. Reentered 7/19
Gorizont 18	1989 052A	USSR	Jul 5	Tyuratam	D-1-e	2,120	1,436.0	35,772	35,798	1.5	Domestic communications. Located above 140 deg. e
Olympus	1989 053A	ESA	Jul 12	Kourou	Ariane	32,595	1,436.2	35,767	35,808	0.0	European high-power commsat technology demonstration. 1st European satellite using 20/30 GHz. Stationed above 19 deg. w long.
Kosmos 2030	1989 054A	USSR	Jul 12	Plesetsk	A-2	6,500	89.6	164	351	67.1	Photo recon. Destroyed by ground command. Reentered 7/29
Resurs-F 3	1989 055A	USSR	Jul 18	Plesetsk	A-2	6,300	89.8	260	275	82.5	Remote sensing. Deployed 2 subsatellites. Reentered 8/8
Pion 3	1989 055C	USSR	Aug 7	Resurs-F	A-2	78	89.7	254	272	82.5	Passive atmospheric research subsatellite. Reentered 9/19
Pion 4	1989 055D	USSR	Aug 7	Resurs-F	A-2	78	89.7	255	272	82.5	Passive atmospheric research subsatellite. Reentered 9/19
Kosmos 2031	1989 056A	USSR	Jul 18	Tyuratam	A-2	6,500	89.3	234	254	50.5	Photo recon. Destroyed by ground command, reentered 8/31
Kosmos 2032	1989 057A	USSR	Jul 20	Plestesk	A-2	6,300	89.9	233	364	82.3	Photo recon. Reentered 8/3
Kosmos 2033	1989 058A	USSR	Jul 24	Tyuratam	F-1	4,000	92.7	404	418	65.0	Eorsat, ocean recon.
Kosmos 2034	1989 059A	USSR	Jul 25	Plesetsk	C-1	825	104.9	969	1,013	82.9	Navigation
Kosmos 2035	1989 060A	USSR	Aug 2	Plesetsk	A-2	6,300	90.3	231	357	82.5	Photo recon. Reentered 8/16
STS-28	1989 061A	US	Aug 8	KSC	Columbia		90.5	314	317	56.9	Crew: Brewster Shaw, commander; Richard Richards, pilot; David Leestma, James Adamson, Mark Brown, mission specialists. Deployed DoD payload. Reentered 8/13, after 5 days, 1 hr.
None	1989 061B	US	Aug 8	Columbia		Elements not available					

Summary Log of Space Launches 1989

Name	Int'l Desig.	Proj. Dir.	Launch Data			Weight (kg)	Orbital Data				Status
			Date	Site	Vehicle		Period	Perigee	Apogee	Incl.	
TV Sat 2	1989 062A	ESA	Aug 8	Kourou	Ariane 44LP	2,130	1,436.2	35,772	35,804	0.0	Direct TV broadcast to West Germany, parts of Europe. Positioned above 19 deg. w long.
Hipparcos	1989 062B	ESA	Aug 8	Kourou	Ariane 44LP	1,130	639.7	542	35,889	6.9	Scientific. Measure positions of stars. Failed to reach geosynch due to AKM malfunction. Good data returned from modified transfer orbit
Resurs-F 3	1989 063A	USSR	Aug 15	Plesetsk	A-2	6,300	89.7	259	268	82.3	Remote sensing. Reentered 9/14
GPS 2-3	1989 064A	US	Aug 18	ESMC	Delta	1,665	718.0	20,111	20,252	55.0	Navstar Global Positioning System
Kosmos 2036	1989 065A	USSR	Aug 22	Plesetsk	A-2	6,300	89.9	250	297	62.8	Photo recon. Reentered 9/5
Progress M-1	1989 066A	USSR	Aug 23	Tyuratam	A-2	7,250	92.3	382	397	51.6	New cargo ship. Resupplied Mir. Docked 8/25; undocked and reentered 12/1
Marcopolo 1	1989 067A	UK	Aug 27	ESMC	Delta	11,220	1,436.2	35,785	35,791	0.0	British direct broadcast. 1st commercial launch for U.S. launcher. Stationed above 31 deg. w
Kosmos 2037	1989 068A	USSR	Aug 28	Plesetsk	F-2	900	116.1	1,485	1,525	73.5	Geodetic (GEO-IK)
None	1989 069A	US	Sep 4	ESMC	Titan 3		Elements not available				
None	1989 069B	US	Sep 4	ESMC	Titan 3		Elements not available				
GMS-4	1989 070A	Japan	Sep 5	Tanegashima	H-1	725	1,436.1	35,780	35,792	1.4	Japanese meteorological satellite. Stationed above 140 deg. e
Soyuz TM-8	1989 071A	USSR	Sep 5	Tyuratam	A-2	7,150	91.3	380	395	51.6	Transported Alexander Viktorenko, Alexander Serebrov to Mir. Docked 9/7. Returned with crew 2/19/90
None	1989 072A	US	Sep 6	WSMC	Titan 2		Elements not available				
Resurs-F 4	1989 073A	USSR	Sep 6	Plesetsk	A-2	6,300	89.9	262	273	82.3	Remote sensing. Carried Cossima microgravity exp. for FRG. Reentered 9/22
Kosmos 2038	1989 074A	USSR	Sep 14	Plesetsk	F-2	100	113.8	1,415	1,433	82.5	Communications
Kosmos 2039	1989 074B	USSR	Sep 14	Plesetsk	F-2	100	113.8	1,412	1,431	82.5	Communications
Kosmos 2040	1989 074C	USSR	Sep 14	Plesetsk	F-2	100	114.1	1,425	1,443	82.5	Communications
Kosmos 2041	1989 074D	USSR	Sep 14	Plesetsk	F-2	100	113.9	1,415	1,436	82.5	Communications
Kosmos 2042	1989 074E	USSR	Sep 14	Plesetsk	F-2	100	113.9	1,420	1,436	82.5	Communications

Summary Log of Space Launches 1989

Name	Int'l Desig.	Proj. Dir.	Launch Data			Weight (kg)	Orbital Data				Status
			Date	Site	Vehicle		Period	Perigee	Apogee	Incl.	
Kosmos 2043	1989 074F	USSR	Sep 14	Plesetsk	F-2	100	114.0	1,422	1,440	82.5	Communications
Kosmos 2044	1989 075A	USSR	Sep 15	Plesetsk	A-2	6,000	89.2	207	267	82.3	Life sciences. Housed monkeys, rats, fish, insects, plants. 29 U.S./Soviet cooperative experiments conducted on returned specimens. Reentered 9/29
Kosmos 2045	1989 076A	USSR	Sep 22	Tyuratam	A-2	6,300	89.1	235	390	69.9	Photo recon. Reentered 10/2
FltSatCom F-8	1989 077A	US	Sep 25	ESMC	Atlas	2,310	1,436.2	35,776	35,799	4.8	Military communications. Last in a series of 8. Final Atlas launch for NASA
Molniya 1-76	1989 078A	USSR	Sep 27	Plesetsk	A-2-e	1,800	717.5	636	39,704	62.9	Domestic communications
Kosmos 2046	1989 079A	USSR	Sep 27	Tyuratam	F-1	4,000	92.8	405	417	65.0	Eorsat. Ocean recon.
Interkosmos 24 (Activny)	1989 080A	USSR	Sep 28	Plesetsk	F-2	1,000	115.9	505	2,492	82.6	Particles & fields exps. U.S. participation
Magion-2	1989 080B	USSR	Oct 3	Plesetsk	F-2	50	115.9	504	2,494	82.5	Czechoslovakian-built subsatellite. Receives signals from Interkosmos 24 for propagation exp.
Gorizont 19	1989 081A	USSR	Sep 28	Tyuratam	D-1-e	2,120	1,436.8	35,783	35,792	1.4	Domestic communications. Located above 97.5 deg. e
Kosmos 2047	1989 082A	USSR	Oct 3	Plesetsk	A-2	6,500	89.5	167	333	67.1	Photo recon. Reentered 11/21
Kosmos 2048	1989 083A	USSR	Oct 17	Plesetsk	A-2	6,300	90.4	239	359	62.8	Photo recon. Reentered 10/26
STS-34	1989 084A	US	Oct 18	KSC	Atlantis	119,943*	90.5	295	323	34.3	Crew: Donald Williams, commander; Michael McCulley, pilot; Shannon Lucid, Franklin Chang-Diaz, Ellen Baker, mission specialists. Deployed Galileo. Landed 10/23 after 4 days, 23 hrs, 39 mns.
Galileo	1989 084B	US	Oct 18	STS	IUS	3,881**	Venus-Earth-Earth-Gravity-Assist trajectory				Jupiter probe with flybys of Venus, earth, an asteroid before arriving at fifth planet, 12/95. Venus flyby 2/90. Data will be returned 11/90 as spacecraft nears earth
GPS 2-4	1989 085A	US	Oct 21	ESMC	Delta	1,665	719.9	20,079	20,283	54.7	Navstar Global Positioning System
Meteor 3-3	1989 086A	US	Oct 24	Plesetsk	F-2	2,150	109.4	1,190	1,213	82.5	Meteorological

*Total liftoff weight was 2,049,285 kg

**Includes 335-kg probe

Summary Log of Space Launches 1989

Name	Int'l Desig.	Proj. Dir.	Launch Data			Weight (kg)	Orbital Data				Status
			Date	Site	Vehicle		Period	Perigee	Apogee	Incl.	
Intelsat VI-2	1989 087A	Intel.	Oct 27	Kourou	Ariane 44L	4,215	1,436.1	35,737	35,837	0.1	New generation Intelsat. Positioned above 24.5 deg. e
Kosmos 2049	1989 088A	USSR	Nov 17	Plesetsk	A-2	7,000	89.3	235	289	64.7	Photo recon.
COBE	1989 089A	US	Nov 18	WSMC	Delta	2,265	102.8	886	895	99.0	Cosmic Background Explorer. Measuring infrared radiation
STS-33	1989 090A	US	Nov 23	KSC	Discovery	Elements not available					Crew: Frederick Gregory, commander; John Blaha, pilot; Manley Carter, Story Musgrave, Kathryn Thornton, mission specialists. Deployed DoD payload. Landed 11/28 after 5 days, 8 mns
None	1989 090B	US	Nov 23	STS	IUS	Elements not available					
Kosmos 2050	1989 091A	USSR	Nov 23	Plesetsk	A-2-e	1,900	717.9	616	39,747	63.0	Early warning
Kosmos 2051	1989 092A	USSR	Nov 24	Tyuratam	F-1	4,000	92.8	405	416	64.9	Eorsat. Ocean recon.
Kvant 2	1989 093A	USSR	Nov 26	Tyuratam	D-1	19,565	92.4	394	399	51.6	Mir service expansion module. Docked with front axial port 12/6; moved by docking arm to upper radial port 12/8
Molniya 3-36	1989 094A	USSR	Nov 28	Plesetsk	A-2-e	1,800	717.8	662	39,694	62.8	Domestic communications
Kosmos 2052	1989 095A	USSR	Nov 30	Plesetsk	A-2	6,500	89.4	181	345	67.1	Photo recon. reentered 1/24/90
Granat	1989 096A	USSR	Dec 1	Tyuratam	D-1-e	3.5 t	5,928.0	1,764	202,482	51.8	X-ray, gamma ray observatory studying high-energy emissions. Carries French, Bulgarian, Danish exp.
GPS 2-5	1989 097A	US	Dec 11	ESMC	Delta	21,665	718.1	20,010	20,359	54.9	Navstar Global Positioning System
Raduga 25	1989 098A	USSR	Dec 15	Tyuratam	D-1-e	1,965	1,436.3	35,767	35,815	1.5	Domestic communications. Stationed above 45 deg. e
Progress M-2	1989 099A	USSR	Dec 20	Tyuratam	A-2	7,250	92.4	393	395	51.6	Resupplied Mir. Docked 12/22. Carried U.S. microgravity payload. Reentered 2/9/90
Kosmos 2053	1989 100A	USSR	Dec 27	Plesetsk	F-2	3,000	95.1	512	534	73.5	Minor Military
Kosmos 2054	1989 101A	USSR	Dec 27	Tyuratam	A-1-e	2,150	1,435.8	35,706	35,859	1.4	Communications. Located above 346 deg. e

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